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REPORT ON THE INVESTIGATIONS

INTO THE

PURIFICATION

OF THE

OHIO RIVER WATER

FOR THE

IMPROVED WATER SUPPLY OF THE
CITY OF CINCINNATI, O.

1899

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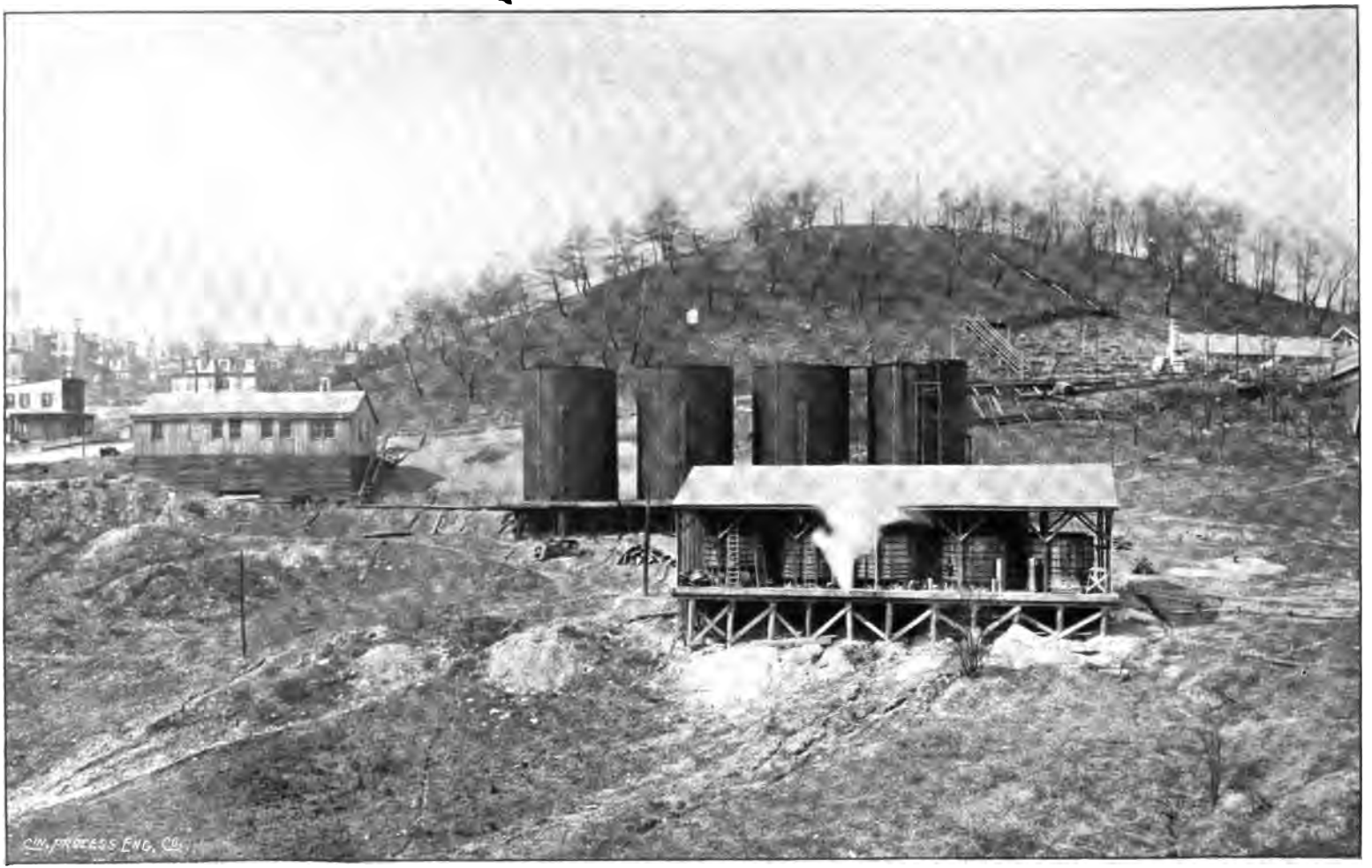

GENERAL VIEW OF EXPERIMENTAL PLANT.

REPORT ON THE INVESTIGATIONS

INTO THE

PURIFICATION

OF THE

OHIO RIVER WATER

FOR THE

IMPROVED WATER SUPPLY OF THE CITY OF CINCINNATI, O.

MADE BY THE BOARD OF TRUSTEES, COMMISSIONERS OF WATERWORKS.

CINCINNATI:
COMMERCIAL GAZETTE JOB PRINT.
1899

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COMMISSIONERS OF WATERWORKS

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CHAS. HERMANY.

CHIEF CHEMIST AND BACTERIOLOGIST:—

GEORGE W. FULLER.

Prefatory Note.

On January 17, 1899, just before there were completed the investigations which were undertaken by the city in accordance with the resolutions of November 26, 1897, the Board resolved to make an official test of a system of purification proposed by the Ohio Sanitary Engineering Company.

As a matter of convenience the report upon the test referred to above is presented in the same volume with that upon the investigations originally provided for by the city, and is called "Part II." It is to be noted that each Part has a separate Index at the end of the volume.

136389

ERRATA.

On pages 85 (line 26) and 90 (line 9) read "Plate XI" instead of Plate XII.

On page 576, at end of line 14, please add: "It is to be stated as a matter of record, however, that even with this efficiency the effluent showed the presence of *Bacillus coli communis* when fifty cubic centimeters of water were employed for the tests."

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PART I.

Report upon the Results obtained from Investigations into the Purification of the Ohio River Water, conducted by the City of Cincinnati,

MARCH 28, 1898, TO JANUARY 25, 1899.

CINCINNATI, O., February 17, 1899.

BOARD OF TRUSTEES, "COMMISSIONERS OF WATERWORKS,"
CINCINNATI, OHIO:

GENTLEMEN,—I transmit herewith the final report of Mr. George W. Fuller, Chief Chemist and Bacteriologist, upon the operation of the Experimental Water Purification Plant at Eden Park, from March 28, 1898, to January 31, 1899.

The results obtained by different methods of treatment of the Ohio River water under varying conditions are given with great detail, and the conclusions arrived at by Mr. Fuller, after a critical analysis of these results, is deserving of your most careful consideration.

Respectfully,

G. BOUSCAREN,
Chief Engineer.

J. BOUSCAREN, ESQ., *Chief Engineer,*

Board of Trustees, "Commissioners of Waterworks,"

Cincinnati, Ohio:

DEAR SIR,— Herewith is presented the full report upon the entire operations of the experimental purification plant.

OBJECT OF THE WORK.

This work had for its object an investigation into the practicability of the method proposed by the Engineer Commission (1896), by which, as a part of the extension and betterment of the municipal water supply, the Ohio River water should be partially clarified by plain subsidence for several days and then filtered, as suggested, through filters of the English type.

Owing to the fact that the Ohio River water at Cincinnati differs materially in its character for about six months in the year from those waters where this method of purification has been long successful, it was recommended both by the Board of Expert Engineers (1897) and the Chief and Consulting Engineers of the present Board that, before proceeding further, sufficient reliable data should be obtained with reference to the exact local conditions.

PLAN OF PROCEDURE.

It was decided to take the interest for one year on the probable cost of a filter plant, estimated roughly at $1,000,000; construct an experimental purification plant, representative

of the system of purification which had been suggested for the local supply; operate this plant for about eight months, including some of the most difficult types of the local river water to purify; and secure during the operation adequate data along the necessary engineering, chemical, and bacterial lines.

GENERAL ACCOUNT OF THE EXPERIMENTAL PLANT AS ORIGINALLY DESIGNED.

The experimental purification plant was located on city property below and adjoining the retaining wall of the Eden Park reservoir, where it could receive from the force mains the river water on its way to the reservoir. It had a capacity of 100,000 gallons per day. In brief terms the plant included the following principal parts:

1. Four steel tanks of an available capacity of 100,000 gallons each, to be used for the preliminary treatment of the river water by plain subsidence.

2. Fifteen experimental filters of an area of 1-400 acre each, receiving the subsided water and representing different kinds of local sand, different thicknesses of sand layers, and different rates of filtration.

3. An office and laboratory building of a temporary nature, equipped with necessary apparatus and supplies to allow an extended series of chemical and bacterial analyses to be made, according to the most approved methods, of the water before, during, and after its treatment by this system.

The appurtenances of this plant included the necessary valves, meters, gages, and other devices and tools for its operation, and for a careful record thereof.

Practically without exception, all of the filtered water was discharged into the low-service main in Third Street.

AMPLIFICATIONS AND MODIFICATIONS IN THE EXPERIMENTAL PLANT.

In the course of the operation of the experimental plant, the results showed clearly the necessity of stopping a portion of the plant and of making additions, such that there could be tested modified procedures more applicable to the local conditions than the original ones. These amplifications were three in number, as follows:

1. On August 1, 1898, seven of the original filters were permanently stopped and the tanks emptied of the filtering materials. Two new filters, constructed in old tanks, were placed in operation on August 8, to be used in conjunction with a coagulating and subsiding basin, the latter having a capacity of about ten hours' normal flow of water for these filters. At times of muddy water in the river, the plain subsided water was given a supplementary clarification before its application to the filters, with the aid of a coagulant and this extra subsidence. When the river water was fairly clear, no coagulant was used with this modified system.

2. During August a study was made of the best source from which to secure satisfactory filtering sand from the bars in the Ohio River, near the new works at California. To determine whether or not it would be advisable to wash the sand before its placement in a filter, two new filters, constructed in old tanks, were placed in operation on September 1.

3. During September all of the original experimental filters were stopped, except the most efficient one, in order to use the subsided water in the operation of a small American (mechanical) filter provided with coagulating basins. The object of these tests (beginning September 14) was to obtain

directly comparable data with those from the August modification as to the most practicable method of using coagulants in connection with the treatment of plain subsided water.

A number of small modifications were made from time to time, in the study of special problems, related chiefly to washing the sand and to the coagulation of the water under different conditions.

PERIOD OF INVESTIGATION AND DISTRIBUTION OF TIME.

The writer was appointed on December 3, 1897, to take direct charge of these investigations under the direction of the Chief Engineer. Plans were completed and contracts were let during that month. The construction of the experimental plant occupied the months of January, February, and a part of March, 1898. During the latter part of this time the laboratory was equipped and placed in readiness for regular work.

On March 28, 1898, the plant was placed in regular operation, the subsiding tanks having been filled with river water prior to this date in order to supply the filters with subsided water from the outset. From this date the plant as a whole was kept in continuous operation, with no interruption of importance until the close of the tests on January 25, 1899.

Portions of the plant, however, were permanently stopped during the tests and new portions added and operated, as stated in the last section.

During the last two months of operation portions of the plant in turn were permanently stopped in order to allow the prompt preparation of this report.

AMOUNT OF ANALYTICAL WORK.

To determine the character of the water before and after purification, and thereby the efficiency of the methods under

consideration, 1205 samples of water were analyzed chemically and 9855 samples bacterially. In addition to this the weight of suspended matters was determined in 561 special samples.

FORCE EMPLOYED.

The regular force employed in conducting these investigations consisted of eight men besides the writer. There were two attendants in addition to the corps of trained assistants, as follows:

Mr. Chas. L. Parmelee,	Assistant Engineer.
Mr. Joseph W. Ellms,	Assistant Chemist.
Mr. Geo. A. Johnson,	Assistant Bacteriologist.
Mr. Alex. N. Miller,	Assistant.
Mr. J. C. Beneker,	Assistant.
Mr. Leon Tedesche,	Assistant.

To these gentlemen the writer desires to express his appreciation of their faithfulness and industry, to which the success of the work was largely due. He also wishes to record his obligation to the Chief Engineer for his courteous attention and frequent advice during the conduct of these investigations.

In addition to the regular force it was necessary to employ in varying numbers carpenters, pipe-fitters, and laborers to make the required repairs, alterations, and additions. Exclusive of the original construction and grading, this special force averaged seven men for the ten months.

COST OF THE INVESTIGATIONS.

The total cost of these investigations, December 3, 1897, to January 31, 1899, inclusive, was $38,260.29. This sum was distributed as follows:

Foundations (including labor)	$5,977 72
Settling tanks	4,933 40
Filters (20)	2,995 13
Laboratory building ($1,139.35) and shed over filters ($815.20)	1,754 55
Piping system (including labor)	5,195 74
Fittings of laboratories (piping, benches, sinks, etc.)	830 57
Office furnishings and supplies	247 11
Equipment of laboratories (apparatus and supplies)	2,228 90
General supplies (including tools, coal, gas)	1,016 67
Salaries	12,973 00
Incidentals	107 50
Total	$38,260 29

In the consideration of the total cost it is to be borne in mind that, upon the abandonment of the plant, the Board has a good laboratory equipment, and many things of more or less market value.

BRIEF OUTLINE OF REPORT.

This report begins with a description and record of the analytical data showing the composition of the Ohio River water at Cincinnati. There is next presented in logical and chronological order a description and record of the several steps taken, with the view to determining the most practical method of clarifying and purifying the local water, together with a discussion of the principal features of each step or process.

The report ends with a resumé of the practical lessons learned from the investigations. For convenience and explicitness the report is divided into ten chapters, and it was the purpose in preparing it to arrange the presentation so that the introduction and final chapter would cover the premises and main deductions of the investigations. The intervening chapters are devoted chiefly to summaries of the leading data, with necessary descriptions and discussions. In a series of appendices are given the more detailed data.

The scope of the work is made plainer by the following list of chapters and appendices into which the report is divided:

LIST OF CHAPTERS.

Chapter I.—Composition of the Ohio River water at Cincinnati.

Chapter II.—Description of the experimental purification plant.

Chapter III.—Manner of operation of the subsiding tanks and the efficiency of plain subsidence for two to three days in the clarification and purification of Ohio River water.

Chapter IV.—Description of the operation of the original English filters receiving plain and subsided water, and a summary of the principal results accomplished therewith.

Chapter V.—Discussion of the leading factors associated with the efficiency and cost of operation of the English filters receiving plain subsided water, based on the results of these experiments.

Chapter VI.—Description of the operation of the modified English system, and a summary of the principal results accomplished therewith.

Chapter VII.—Discussion of the leading factors associated with the efficiency and cost of operation of the modified English system of purification, based on the results of these experiments.

Chapter VIII.—Description of the operation of the American system of purification receiving plain subsided water, and a summary of the principal results accomplished therewith.

Chapter IX.—Discussion of the leading factors associated with the efficiency and cost of operation of the American system of purification, based on the results of these experiments.

Chapter X.—Final resumé and conclusions.

Appendices.—Containing detailed engineering and analytical evidence.

CHAPTER I.

Composition of the Ohio River Water at Cincinnati.

At Cincinnati the Ohio River water varies in its composition to a degree which is extreme when compared with that of the ordinary streams on the glacial drift formation of the Atlantic seaboard; and approaches, but does not reach, the variability of the water of the lower Ohio River.

It may be stated in explanation of this variability that it is due principally to a combination of factors associated with the size, geological and topographical character of the watershed, and with the amount, rate, and frequency of the rainfall throughout the valley.

MOST CHARACTERISTIC FEATURES OF THE OHIO RIVER WATER AT CINCINNATI.

At the outset it is imperative, for a clear understanding of this report, that there should be fixed in mind the two most characteristic features of the local river water, as follows:

1. The wide range in the amount of suspended matter present in the water.

2. The great variations in the nature of the suspended matter, and especially in the size of the particles.

A comprehensive idea of the amounts of suspended matter

found at different times in this water during the year 1898 is shown in the following summary:

Number of Days. 1898.	Corresponding Range of Suspended Matter. Parts per Million.
0	Less than 10
41	11— 50
63	51— 100
127	101— 250
99	251— 500
29	501—1000
5	1001—2000
1	Over 2000
Average	280

Relative to the great variations in the character and size of the suspended matters, this is best illustrated by the following table, in which there is indicated the different hydraulic subsiding values (or sizes) of two extreme types of the river water. Type I is characteristic of the water during the early portion of a heavy freshet, when the water is heavily laden with silt and fairly coarse clay, and type II is representative of the water during latter portions of rises, while it is charged to a greater relative degree with very fine, minute particles of clay.

Periods of Subsidence—Hours.	Suspended Matter in Parts Per Million.		Per Cent Removed.	
	Type I.	Type II.	Type I.	Type II.
0	2333	205	0	0
1	932	81	60	55
3	653	80	72	56
6	396	79	83	56
12	350	73	85	58
24	300	61	87	63
48	259	44	89	67
72	210	36	91	70
96	186	31	92	72

Between types I and II there are found in the course of a year almost an endless number of intermediate combinations.

PRACTICAL IMPORTANCE AND SIGNIFICANCE OF THE VARIABILITY OF THE RIVER WATER.

From the foregoing there will be appreciated the great variability of the Ohio River water at Cincinnati, and the necessity of frequent analyses to learn its composition. As will be brought out more clearly in subsequent chapters, it is imperative in the premises that, in order to deduce the most practicable principles upon which to base the construction of a purification plant, and to operate such a plant, there should constantly be at hand a substantially correct knowledge as to the composition of the water in several particulars. Furthermore, a purification plant applicable to this river water must be more comprehensive and elaborate than for most water now filtered, because the turbidity of this water is so great that steps are necessary at times to clarify the river water partially before it is applied to the filters.

Naturally, this chapter is composed chiefly of the results of analyses; but, before coming to those data, it is desired to show in a general way what are the factors which cause such great variations in this water, and also consider to what degree those factors were normal during the year 1898.

The direct causes of these variations in the Ohio River water are the rises or freshets which are so characteristic of this stream. Indirectly there are a number of factors which exert much influence. Among them are the amount, rate, distribution, and frequency of the rainfall in the valley, and also the surface geology, topography, area, and length of the watershed, and the condition of the soil at the time of the heavy rains. To solve the problem of establishing the relation

between the composition of this river water and the factors affecting it is a complex matter; and so far as our knowledge goes there are available no adequate data for the purpose, nor are such data being obtained.

We shall refer briefly to these several factors, especially with the view to showing the probable degree to which this water was normal in its composition during the period covered by these investigations.

THE OLD AND NEW INTAKES OF THE CINCINNATI WATERWORKS.

Mention will be frequently made in this chapter to the intakes of the old works and of the new works, and their relative locations will be explained here.

The present intake at the Front Street Pumping Station, from which was pumped the water used in these investigations, is opposite the upper portion of the city and below the mouth of the Little Miami River, and there are at least thirty-two small sewers and drains discharging into the river between it and the tributary stated. The new intake will be at California, about seven miles above the Front Street intake and about one mile above the mouth of the Little Miami River.

AREA OF WATERSHED.

The watershed of the Ohio River above the intake of the new Cincinnati Waterworks at California has an area of about 70,600 square miles. This area includes portions of the States of Ohio, New York, Pennsylvania, Virginia, North Carolina, West Virginia, and Kentucky.

Above the intake of the Front Street Pumping Station (used during these tests) the area of the watershed is estimated at 72,400 square miles. In addition to the area at the new intake,

the last area includes that of the watershed of the Little Miami River, and that of the Ohio River itself between the Little Miami and the Front Street intake, a distance of about six miles.

About half a mile down stream from the Front Street intake the Licking River empties into the Ohio River on the Kentucky side. At this point the normal width of the river is about 1,000 feet. The Front Street intake is situated about 200 feet from the Ohio shore, and in a straight line is distant about 4,000 feet from the mouth of the Licking. Under some conditions of river stages and of wind-storms the waters of the Licking reach the Front Street intake.

The Licking River has a watershed of about 3,300 square miles. Adding this to the above, there is obtained 75,700 square miles as the total area of the watershed of the Ohio River above the present intake opposite the city.

URBAN POPULATION OF WATERSHED.

The urban population for the year 1900 on the watershed above the new intake is estimated at 1,733,000, and above the present Front Street intake at 1,770,000. These figures are based on the authority of the Ohio State Board of Health.

With regard to the estimate of 37,000 as the population draining into the waters of the Ohio and Little Miami between the old and new intakes, it may be added that the figures seem quite reasonable, although its accuracy is difficult to confirm with precision. It is a fact, however, that a considerable proportion of this population uses sewers which discharge into the Ohio within three miles of the present intake.

GEOLOGICAL FORMATION OF WATERSHED.

To give a comprehensive account of the geological formation of the Ohio Valley and of the valleys of its tributaries is beyond

the scope of this report. It is necessary, however, that there should be borne in mind the leading geological characteristics and the opportunities afforded them to exert an influence upon the amount and character of matters suspended in the water at times of heavy rains.

Speaking in general terms, the leading geological features of this watershed are the large proportion of clay-bearing regions as distinguished from the glacial drift formation; the great variability of the formation at different places in the valley; and the irregular topography which facilitates the eroding action of the water coming from the various tributaries and sub-tributaries.

COMPARISON OF THE RAINFALL IN THE OHIO VALLEY DURING 1898 WITH THE NORMAL.

The United States Department of Agriculture has in the Ohio Valley a number of stations where the rainfall is recorded, and the records of which are sufficient to show the general rainfall for the year 1898, as compared with the normal. From the following tabulation the relative location of these stations can be noted:

List of Principal Rainfall Stations in Ohio Valley.

STATIONS.	Distance by river from Cincinnati.	Location with Reference to Tributaries.
Portsmouth, O.....	118 miles	Mouth of the Scioto River.
Catlettsburg, Ky.....	152 "	Mouth of the Big Sandy River.
Point Pleasant, W. Va.....	204 "	Mouth of the Great Kanawha River.
Parkersburg, W. Va.	286 "	Mouth of the Little Kanawha River.
Marietta, O.....	296 "	Mouth of the Muskingum River.
Wheeling, W. Va..	376 "	On the Ohio River.
Pittsburg, Pa.	466 "	Junction of the Allegheny and Monongahela rivers.
Oil City, Pa.....	536 "	On the Allegheny, 70 miles above Pittsburg.

Table Showing the Monthly Rainfall in Inches at various Stations in the Ohio River Valley for the Year 1898.

	Jan.	Feb.	Mar.	Apr.	May	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Cincinnati, O.	7 76	2 21	6 70	1 15	3 03	1 58	3 26	2 61	2 62	2 90	2 69	2 46	38 97
Portsmouth, O.	10 03	1 69	5 14	2 05	3 53	3 13	5 27	6 92	1 97	3 59	2 54	2 76	48 62
Catlettsburg, Ky.	8 05	2 48	6 93	2 19	4 83	4 52	4 84	6 93	2 10	4 14	2 65	2 83	52 49
Pt. Pleasant, West Va.	8 04	1 93	5 81	1 48	3 51	2 87	2 79	6 40	2 07	3 15	2 67	2 57	43 29
Parkersburg, West Va.	5 73	2 24	5 43	2 17	2 76	4 98	4 38	4 66	2 09	3 90	2 50	2 16	43 00
Marietta, O.	5 74	2 39	6 03	2 30	2 77	5 04	5 20	5 31	3 69	4 24	3 15	2 21	48 07
Wheeling West Va.	4 97	2 50	5 15	3 72	3 63	2 98	5 81	7 82	3 24	3 37	2 66	3 03	48 93
Pittsburg, Pa.	3 40	1 60	5 45	1 60	3 99	3 98	2 56	4 01	1 06	3 85	2 34	1 90	35 74
Oil City, Pa.	5 32	2 53	5 74	2 13	4 64	4 56	4 45	6 73	2 11	5 18	4 83	2 90	50 62

Table Showing the Normal Monthly Rainfall in Inches at the various Stations in the Ohio River Valley.

	Jan.	Feb.	Mar.	Apr.	May	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Cincinnati, O.	3 5	3 7	3 3	3 2	3 4	4 4	3 4	3 7	2 4	2 4	3 3	3 2	39 9
Portsmouth, O	3 5	3 2	3 5	3 2	3 5	4 0	3 9	3 4	2 8	2 8	2 9	3 5	40 2
Catlettsburg, Ky.	4 3	4 0	4 2	3 2	4 0	3 8	4 4	3 6	2 9	2 7	3 5	2 9	43 5
Pt. Pleasant, West Va.	3 5	4 1	3 9	3 7	3 5	4 2	4 4	4 0	2 4	2 4	3 1	2 7	41 9
Parkersburg, West Va.	3 9	3 8	3 0	3 2	3 5	4 0	4 4	3 8	3 1	2 3	2 8	2 3	40 1
Marietta, O.	3 1	3 1	3 2	3 3	3 9	4 1	4 4	3 9	3 1	3 1	3 1	3 4	41 7
Wheeling, West Va.	3 4	3 1	2 6	2 8	4 1	3 7	3 7	4 1	2 8	2 6	2 7	3 0	38 6
Pittsburg, Pa.	2 6	2 5	2 8	3 0	3 5	3 6	4 0	3 4	2 9	2 8	2 6	2 9	36 6
Oil City, Pa.	3 3	3 6	2 8	2 7	3 9	4 6	3 6	2 7	3 4	2 6	3 2	2 8	39 2

Comparison by Months of the Average Stage of the Ohio River at Cincinnati for the Year 1898 *with the Normal.*

With a rainfall throughout the Upper Ohio Valley not more than about ten per cent in excess of the normal on an average, it is natural to expect that the average stage of the river at

Cincinnati would be approximately normal during the year covered by these investigations. That such was practically the case is shown by the average stages of the river in feet in the following table:

	1889.	1890.	1891.	1892	1893.	1894.	1895.	1896	1897.	1898.	Average.
January.....	25.4	33.0	31.8	23.2	13.0	17.3	28.2	14.1	14.2	35.5	23.6
February.....	21.6	38.1	47.1	24.6	41.0	27.3	13.2	23.4	36.9	24.8	29.8
March	21.0	45.2	36.9	25.6	25.8	22.6	27.3	22.8	39.9	31.6	29.9
April.....	18.3	33.2	30.2	31.4	26.9	18.8	24.3	25.8	26.1	26.9	26.2
May	15.9	32.7	9.8	24.6	35.9	17.0	12.7	12.2	23.2	23.7	20.8
June.....	25.1	19.5	18.9	22.7	14.8	12.0	6.4	11.9	12.7	11.4	15.5
July..... ..	18.8	10.1	12.8	11.6	8.2	5.6	7.5	22.2	14.2	8.6	12.0
August.....	12.1	10.1	11.3	7.7	4.8	4.3	6.1	19.7	10.0	20.2	10.6
September...	6.9	20.6	9.3	5.7	7.0	4.8	4.8	6.7	4.7	7.7	7.8
October.....	8.0	22.3	4.8	4.2	10.4	4.6	2.9	14.8	3.5	9.6	8.5
November....	24.8	24.3	9.9	6.4	9.5	6.7	3.4	14.1	8.1	17.6	12.5
December....	23.7	17.1	18.9	11.1	16.6	12.0	9.5	19.8	17.6	18.5	16.5
Average.....	18.9	25.5	20.2	16.5	17.8	12.7	12.2	17.2	17.4	19.7	*17.8

*Average 1858 to 1898 inclusive, 17.2.

COMPARISON OF THE FREQUENCY, INTENSITY, AND DURATION OF RISES OR FLOODS IN THE OHIO RIVER AT CINCINNATI DURING 1898 WITH THE NORMAL.

This subject is one of great importance from a practical standpoint, because it deals with the factors which directly produce the large quantities of and variations in the matters suspended in the river water. In view of the fact that these suspended matters are a point of vital significance in connection

with the construction of an applicable system of clarification and purification, and also in the efficiency and economy of its operation, it is necessary to know, at least in general terms, how nearly normal was the suspended matter during these tests; and, further, it would be very desirable to be able to foretell the conditions with regard to the suspended matters due to rises, as an aid in the operation of a plant.

To accomplish these purposes involves a study of the frequency, intensity, and duration of the rises in the river. It is an easy matter to deal with the first of these factors, except when the rises overlap each other; but to establish a relation between suspended matter, both in amount and character, and the intensity and duration of rises is a very difficult and perplexing problem. At the beginning of a freshet the rapidity with which the water rises seems to be a great factor, and the more rapid is the rise, the greater is the amount of suspended matter and also the percentage of silt. When the rise is of long duration it is found that, with the waters coming from the head of the valley, the weight of suspended matters gradually decreases, but the percentage of clay steadily increases owing to the deposition of silt in the stream itself.

Just how it is best to arrange the available data to throw light upon these points is not wholly clear to us, since all efforts in this direction are wholly arbitrary and of necessity incomplete. However, it is believed that a comparison of the intensity and number of rises in the river with the rises for the past ten years will give as good a comparison for this purpose as can be obtained. In the following table, therefore, are given the number of days on which the river was rising moderately, rapidly, very rapidly, and when there was developing an extreme freshet:

Number of Days in a Year on which the Ohio River was Rising at Various Rates during the last Ten Years.

Year.	Rate of Rise in Feet per Day.			
	1.0—2.9.	3.0—5.9.	6.0—11.9.	Over 12.
1889	66	12	3	0
1890	63	31	4	0
1891	44	24	2	0
1892	33	10	5	1
1893	44	23	2	0
1894	24	8	4	0
1895	26	11	5	1
1896	47	24	2	0
1897	45	21	2	1
1898	54	25	7	0
Average	44.6	18.9	3.6	0.3

SYNOPSIS OF THE LEADING FEATURES OF THE OHIO RIVER WATER AT CINCINNATI DURING A NORMAL YEAR.

Before outlining briefly the general character of the Ohio River water, it is desired to place on record, as a matter of convenience for reference, the maximum, minimum, and normal amounts to which the several principal constituents were found in the water during 1898, as follows:

Summary of the Amounts of the Several Constituents Found in the River Water for the Year 1898.

Constituents.	Parts per Million.		
	Maximum.	Minimum.	Normal.
Total suspended matter	2333.0	24.0	230.0
Suspended organic matter (nitrogen as albuminoid ammonia)	0.758	0.022	0.200
Total dissolved residue	228.0	67.0	120.0
Total nitrogenous organic matter	0.868	0.106	0.290
Nitrogen as free ammonia	0.074	0.008	0.025
Nitrogen as nitrites	0.030	0.000	0.003
Nitrogen as nitrates	1.34	0.37	0.60
Chlorine	44.0	3.0	10.0
Sulphuric acid	46.0	13.0	24.0
Incrusting constituents	57.0	11.0	33.0
Alkalinity	70.0	20.0	45.0
Dissolved oxygen	10.0	3.4	7.2
Carbonic acid	47.0	6.0	26.0
Microscopic organisms per cu. centim.	40.0	.....	.....
Bacteria per cubic centimeter	150,000	1,000	20,000

Odor.—The river water ordinarily has a slight odor characteristic of surface waters, the nature and intensity of which are somewhat variable. At different times the odor is musty, aromatic, resinous, and vegetable. The latter is most noticeable after heavy rains during the warmer portions of the year. These odors become more pronounced upon heating the water; but, so far as noted during these tests, there is a practically complete absence of disagreeable or objectionable odors.

Color.—Independent of the suspended matter in it, the normal river water is practically colorless, although in absolute terms it contains a small but measurable amount of color. It seems quite probable that, at times following certain kinds of rises in the river, there is an appreciably larger amount of dissolved color in the water than is normally the case. But experience shows that ordinarily it is easier to remove the unusual amounts of dissolved color than is the case with the

finest particles of suspended clay. After passage through a Pasteur filter or a fine paper filter, the water contains no color which is ordinarily visible.

Taste.—Ordinarily the river water has an earthy taste, which, however, does not become disagreeable except at times of great turbidity. Freed of its suspended matter, this water has a very satisfactory and agreeable taste.

Appearance.—The turbidity of the river water is such that its appearance is almost always unsatisfactory and uninviting, and for about half of the time it is so turbid that it is repulsive when considered for domestic use.

Weight of Suspended Matters.—When expressed in parts by weight per million parts of water by volume, the suspended matters in this water normally range from 20 to 2,500, and average about 230 parts.

Character of Suspended Matters.—In character as well as in amount of suspended matter, the river water possesses a wide and rapidly changing degree of variability. The water in the course of the year contains an almost endless combination of varying proportions of fine sand made up of particles of quartz and hard silicates, with high specific gravity and a diameter larger than 0.002 inch; of silt with its intermediate size, specific gravity and composition; and of very fine clay particles of aluminum silicate with varying degrees of hydration, of low specific gravity and of a size ranging from 0.0002 inch to less than 0.00001 inch.

Amount of Organic Matter.—The organic matter in the river water ranges from an amount which is fairly normal for eastern waters to quantities (during rises) which are excessive, as judged by the data for many years collected from rivers not located in this general section of the country. The local data summarized above are a striking proof of the fact that it is not

the amount but the character of organic matter which is of importance from a sanitary standpoint.

Character and Stability of Organic Matter.—From the immediately adjoining portion of the watershed there is quite an amount of sewage pollution. Owing to the large dilution, the deleterious effect of this is greatly attenuated. By no means is it eliminated at times of comparatively clear water, but during rises this crude organic matter to a considerable degree seems to be united and attached to particles of suspended matter, and thus carried to the bottom.

The consequence of this dilution and sedimentation is that the water contains very little organic matter, except that of a fairly stable character coming from the washings of the surface of the earth. With water taken from the new intake, above the local sources of pollution, this will be true to a still greater degree.

Alkalinity.—The alkalinity is caused by the carbonates and bicarbonates of lime and magnesia, and in a measure corresponds to temporary hardness (bicarbonates). It is the alkalinity which measures the capacity of the water to decompose sulphate of alumina and other coagulating salts. This water contains an average and minimum alkalinity of 45 and 20 parts per million, respectively. By these amounts of alkalinity there can be decomposed, respectively, about 6.5 and 3.0 grains per gallon of sulphate of alumina of ordinary composition, assisted by the average absorption of chemical by the suspended matters in the water.

Incrusting Constituents.—Those constituents of water, which produce incrustations in steam boilers, comprise the sulphates, chlorides, and perhaps nitrates of lime and magnesia. In this water they are present (on an average of 33 parts per million) to a degree greater than in most of the eastern waters, but smaller

than in the waters farther west. On the whole, this water is a good one for boiler purposes, so far as incrusting constituents are concerned.

Gaseous Constituents.—Atmospheric oxygen is apparently present in this water during cold weather to about the limit of saturation, and during the warm season there is contained in the water rather more oxygen than is the case with some surface waters, although the quantity at times becomes only about 40 per cent of that found during the winter. Carbonic acid (carbon dioxide) is present in this water to a degree which is apparently high, according to the limited data available from eastern sources, but much lower than is the case with waters farther west coming from limestone regions.

Taking together the atmospheric oxygen and the carbonic acid, they make the natural conditions quite favorable for the corrosion of unprotected iron receptacles; but the corrosion of lead pipes is promptly arrested by the action of dissolved constituents of the water itself.

Numbers and Kinds of Bacteria.—On an average the numbers of bacteria in the river water (about 20,000 per cubic centimeter) are rather higher than in the ordinary river water. The range is also very great, 1,000 to 150,000, and is associated very intimately with the rises in the river.

At the present point of intake, opposite the city, a considerable number of the bacteria are of sewage origin. These sewage bacteria will be largely absent apparently in the water taken from the new intake at California.

Microscopical Organisms.—The turbidity of the Ohio River water was so great during the large majority of the year 1898, that the sunlight was excluded to a degree practically inhibiting the growth of algæ and similar micro-organisms. When the river water was low and fairly clear, these organisms were

present in considerable numbers, but did not become of practical significance. The dissolved constituents (such as nitrates) in the river water, and especially at times of low water, are well adapted, however, as a food for the organisms which also require sunlight for their development.

COMPOSITION OF THE RIVER WATER AS SHOWN BY THE RESULTS OF ANALYSES.

The remainder of this chapter is devoted to an explanation and record of the analytical evidence upon the composition of this water.

Plan of Analytical Work.

In connection with the analytical work attention was directed to the following points—

1. Physical: Appearance, odor, color, taste, and temperature, and special studies of the amount and character of the suspended matter by optical methods.

2. Chemical: Regular sanitary and technical analyses.

3. Biological: Microscopical examinations. Quantitative bacterial analyses. Identification of species of bacteria, with especial reference to those of sewage origin.

Collection of Samples of Water for Analysis.

From January 10 to March 23, 1898, when the subsiding tanks were placed in regular operation, daily samples of the river water were collected at the Front Street Pumping Station, when convenience permitted, for the determination of the amount of suspended matter.

Beginning with the regular operation of the plant, one chemical sample and two bacterial samples were collected during the filling of each tankful of river water. The records

of the number of bacteria show the average of the results from the two samples collected five minutes apart.

Owing to the fact that changes and modifications in the operation of the plant caused some irregularities in the filling of the subsiding tanks, the samples were not collected at such frequent intervals during the later as in the early portion of the work. The number of samples of river water, analyzed by months, is as follows:

1898—March	4	analyses of	river water.
April	31	"	"
May	31	"	"
June	21	"	"
July	20	"	"
August	21	"	"
September	18	"	"
October	20	"	"
November	20	"	"
December	14	"	"
1899—January	11	"	"

As the work advanced some of the more constant constituents of the water were not determined in each case.

Due to the great turbidity of the river water during a considerable portion of the period, the microscopical organisms (algæ, etc.) were so few that the examinations were omitted as a rule. It is a fact, however, that they were practically absent at times of great turbidity, and from the nature of the method it was almost impossible to examine the water quantitatively for them when it was very turbid.

Examinations were regularly made of each sample of river water for bacillus coli communis, the principal species of the intestinal bacteria. As time allowed, the river water was analyzed with the view to identifying the leading species of bacteria present in the water.

Methods of Analysis.

Physical.—The only point of importance in connection with the methods of physical analysis relates to the optical[1] means of estimating the suspended matter. Intrinsically these results appear to be of rather limited value as applied to the river water at present. In the paper referred to this matter is discussed at length.

Chemical.—The regular sanitary and technical chemical analyses were conducted as described in the report of the Louisville investigations on the same line, with the following exceptions:

1. The loss on ignition of the residue on evaporation and the dissolved alumina were omitted on the ground that they yielded but little data of value, not enough to compensate for the labor involved.

2. Sulphuric acid, by Wildenstein method as described by Ohlmüller, was determined to secure more precise data relative to incrusting constituents. In addition an improvement was made in the method of determining the alkalinity[2] of water.

Biological.—Substantially no divergences from the Louisville methods were practiced in the quantitative determination of the numbers of bacteria present in the water, except that cultivations were made uniformly for three days at 20 degrees C. In passing, however, it may be noted that the methods[3] for the differentiation of species were placed on a somewhat more systematic basis.

[1]See a forthcoming paper in the Technology Quarterly by Charles L. Parmelee and Joseph W. Ellms, on "Rapid Methods for the Estimation of the Weight of Suspended Matters in Turbid Waters."

[2]See a forthcoming paper in the Journal of the American Chemical Society by Joseph W. Ellms, on "The Relative Value of Lackmoid, Phenacetolin, and Erythrosin as Indicators in the Determination of the Alkalinity of Water by Hehner's Method."

[3]See a forthcoming paper in the Journal of Experimental Medicine by George W. Fuller and George A. Johnson, on "The Differentiation and Classification of Water Bacteria."

Physical Character of the River Water.

Supplementary to what has already been said, there is little to add upon the physical character of the Ohio River water at Cincinnati. Considerable effort was made to study the turbidity of the water by optical means, and the light-absorbing power of the suspended matters of many samples of river water were obtained by the platinum wire method, the diaphanometer, and the photo-comparator. These quick optical methods of estimating turbidity, if fairly accurate, would be of great convenience in practice in the operation of a purification plant; but the results in the present state of development of these methods are such that they do not seem to have sufficient specific value to be placed in the regular analytical tables.

The difficulty comes in the data being too erratic and variable to be strictly comparable with each other. When compared with the weight of the suspended matter the turbidity gives some clue to the character of the suspended matter; but, at a purification plant for a water like that of the Ohio River, this would apparently be better and easier obtained at present by the normal observations incidental to operation than with the aid of turbidities of the river water according to present methods.

For further consideration of this topic reference is made to the paper of Messrs. Parmelee and Ellms, which has already been mentioned.

Chemical Character of the River Water.

The next set of tables contains the detailed evidence obtained upon this subject; and as a matter of convenience for comparison the numbers of bacteria are also included.

Explanation of the Results of Chemical Analyses.

A brief explanation is herewith presented of the several points in the table.

Form of Expression.—All of these results are expressed in parts per million. This means in exact terms that one million parts of water by volume contained the several substances in parts by weight to the extent indicated by the figures.

Dividing these figures by 17.1 converts them into grains per United States gallons (231 cubic inches).

Oxygen Consumed.—In this determination there is measured the amount of oxygen which is actually consumed by the organic matter in the water, as it is converted into a comparatively stable form. Nitrogen is not oxidized in this manner, and it is the custom to regard these results as indicative of the carbonaceous matter present in the water.

Nitrogen as Albuminoid Ammonia.—The organic nitrogen in nitrogenous organic matter, when water is distilled with an alkaline solution of potassium permanganate, is converted into ammonia. This ammonia is spoken of as "albuminoid ammonia," and the result of the determination indicates the amount of organic matter of a nitrogenous nature.

In the tables it will be seen that the nitrogen as albuminoid ammonia is subdivided into suspended and dissolved nitrogen. The latter, which is fairly constant, appears at times to be a little too high and at times a little too low. The reason of this is that the result is obtained from the filtrate of a paper filter or a Pasteur filter, and in either case it is possible that a slight amount of dissolved nitrogen may be removed by the filter. In the case of the Pasteur filter it is also possible that the result may be too high owing to a washing out of organic matter from the filter itself. Although these factors have

appeared in this work to a degree which warrants this reference to it, yet the data serve their purpose fairly well in showing that the variations in organic matter lie in the suspended and not in the dissolved substances.

In passing it is fitting, but perhaps needless, to call attention to the fact that, in the case of both the nitrogenous and the carbonaceous organic matter, the actual data have a relative and comparable, but not an absolute, value.

Nitrogen as Free Ammonia.—Without the use of chemicals distillation of water yields in the distillate a small quantity of ammonia. This is called "free ammonia," and it measures the amount of nitrogenous organic matter which has undergone the initial step in the decomposition of organic matter by nature.

This decomposition in nature is accomplished in the presence of oxygen by bacteria, which eventually convert crude organic matter into harmless mineral matter.

Nitrogen as Nitrites.—These results show the amount of organic matter that is in the second intermediate stage of the process in nature, of which the conversion to free ammonia is the first step.

Nitrogen as Nitrates.—It is these results which measure the amount of organic nitrogen which has passed through the cycle of changes, and become completely oxidized and changed into the form of mineral matter.

Chlorine.—For the most part chlorine is present in water as common salt, and, as salt is a prominent constituent of sewage, it is customary to determine chlorine very accurately with the view to regarding it as a measure of sewage contamination. This is facilitated by the fact that chlorine is always present in a soluble form, and does not pass through a cycle of changes as does nitrogen.

In the case of the Ohio River water, however, salt comes more or less from mineral deposits on the watershed; and, accordingly, the value of chlorine determinations is materially reduced.

Sulphuric Acid.—Sulphuric acid is present in water ordinarily in combination with soda, potash, lime, or magnesia, either one or all. Sulphate of lime in fairly large quantities is very objectionable in a boiler water, because it forms an incrustation which is very difficult to remove. From a technical standpoint the amount of sulphuric acid in a water is valuable information.

Incrusting Constituents.—Those constituents of water which form incrustations in steam boilers are the chlorides, sulphates, and perhaps nitrates of lime and magnesia. A determination of these constituents, supplemented by the amount of sulphuric acid, is the most suitable means of recording the applicability of a water for boiler use.

Alkalinity.—This determination for this water registers the quantity of carbonates and bicarbonates of lime and magnesia. In part (bicarbonates) it corresponds to temporary hardness, which can be eliminated by boiling.

With these clay-bearing waters, for which the application of coagulating chemicals is a matter for serious consideration, the alkalinity of the water is a point of vital importance. It measures the capacity of the water to decompose such chemicals.

Taking the sum of the incrusting constituents and the alkalinity, a substantially correct register is obtained of the soap-consuming power of the water.

Residue on Evaporation.—From these results there is learned the total weight of all solid matters which the water contained. This amount is divided into suspended and dissolved residues. The fairly constant dissolved residue was obtained from the filtrate

after passage of the water through a Pasteur filter, and the suspended residue was found by subtracting the dissolved from the total residue. What has been said relative to certain variations at times in the results of the dissolved nitrogenous organic matter also applies to the dissolved residue on evaporation.

Especial attention is called to the suspended residue on evaporation in the following table, because from these results the most comprehensive idea can be obtained of the variability of the water, and of the difficulties in adapting a system of purification capable of meeting the varying demands made upon it.

Iron.—A comparison of the ratios between the iron and the suspended residue on evaporation affords an opportunity of getting a clue as to the general nature of the suspended matter. Practically all of the iron in this water is contained in the suspended matters.

Carbonic Acid.—The Ohio River water at this point contains considerable carbonic acid gas (carbon dioxide) dissolved in the water in the form of free carbonic acid. This determination is of value in studying the corroding action of the water upon iron receptacles.

Dissolved Oxygen.—From the amount of atmospheric oxygen dissolved in the water data are obtained with reference to the corroding action of the water and the utilization of oxygen in the process of nitrification.

Concerning the color, the results refer to dissolved coloring matter, and are expressed according to Hazen's platinum-cobalt standard.

Table Showing the Suspended Matter in Parts per Million in the Ohio River Water at Cincinnati from January 10 *to March* 23, 1898, *with Corresponding Stages of River in Feet.*

Date.	Stage of River.	Suspended Matter.	Date.	Stage of River.	Suspended Matter.	Date.	Stage of River.	Suspended Matter.
1898.			1898.			1898.		
Jan. 10	33.0	2333	Feb. 2	29.5	248	Feb. 22	30.6	147
Jan. 11	32.2	1151	Feb. 3	25.0	372	Feb. 23	31.7	310
Jan. 12	35.4	1024	Feb. 4	21.5	184	Feb. 24	33.0	221
Jan. 13	38.0	719	Feb. 5	18.7	134	Feb. 25	33.2	332
Jan. 14	37.7	578	Feb. 6	16.5	113	Feb. 26	32.4	170
Jan. 15	39.7	470	Feb. 7	14.7	108	Feb. 27	30.7	123
Jan. 16	42.5	483	Feb. 8	14.0	96	Feb. 28	28.0	141
Jan. 17	44.3	416	Feb. 9	13.4	88	Mar. 1	25.0	150
Jan. 19	44.5	308	Feb. 10	13.0	172	Mar. 2	27.6	43
Jan. 21	45.5	358	Feb. 11	13.7	237	Mar. 4	18.7	125
Jan. 22	44.4	285	Feb. 12	16.2	401	Mar. 5	17.5	114
Jan. 23	49.7	401	Feb. 13	17.8	377	Mar. 8	15 4	57
Jan. 24	50.4	535	Feb. 14	19.5	182	Mar. 12	16.3	393
Jan. 25	51.3	522	Feb. 15	23.5	425	Mar. 15	17.6	102
Jan. 26	52 2	601	Feb. 16	27.6	262	Mar. 16	19 0	174
Jan. 27	51.2	533	Feb. 17	30.0	246	Mar. 17	22 6	406
Jan. 28	49 3	292	Feb. 18	31 4	236	Mar. 18	25 2	684
Jan. 29	47.1	269	Feb. 19	30.7	192	Mar. 19	28.6	300
Jan. 30	43.5	207	Feb. 20	31 1	413	Mar. 21	41 0	782
Jan. 31	39 1	57	Feb. 21	30 5	293	Mar. 22	42 3	479
.....	.....	.....	.....	.....	.....	Mar. 23	46 7	478

Jannary 10 to March 23, 1898, was the period of construction of the plant.

Results of Chemical and Bacterial

[*Chemical Results Expressed*

Collected. Date.	Hour.	Temperature. Degrees Centigrade.	Color.	Oxygen Consumed.	Nitrogen as Albuminoid Ammonia. Total.	Suspended	Dissolved.	Free Ammonia.	Nitrites.	Nitrates.
1898										
March 24	5:00 PM	11	.17	7.9	.472	.374	.098	.026	.007	0.60
" 25	10:00 AM	11	.20	10.1	.414	.320	.094	.026	.004	1.00
" 25	5:00 PM	10	.27	11.1	.422	.328	.094	.044	.006	1.10
" 26	10:30 AM	11	.17	8.7	.340	.248	.092	.024	.007	1.00
" 29	5:15 PM	10	.17	8.6	.398	.312	.086	.034	.007	1.20
" 31	1:45 PM	10	.15	6.3	.260	.168	.092	.036	.016	0.70
April 1	1:15 AM	10	.17	5.2	.216	.132	.084	.032	.015	1.00
" 2	6:00 AM	9	.16	5.6	.200	.118	.082	.032	.006	0.60
" 3	7:25 AM	7	.20	4.6	.260	.180	.080	.024	.003	1.00
" 4	10:00 AM	10	.12	5.5	.220	.144	.076	.026	.004	0.90
" 5	9:45 AM	8	.12	4.9	.262	.184	.078	.026	.003	0.90
" 6	9:45 AM	8	.12	8.0	.330	.250	.080	.032	.001	0.90
" 7	10:30 AM	8	.10	5.9	.256	.178	.078	.024	.004	1.00
" 8	8:45 AM	8	.09	4.9	.202	.130	.072	.024	.005	1.00
" 9	12:15 PM	9	.09	7.2	.316	.240	.076	.032	.006	1.00
" 10	1:00 PM	10	.09	5.0	.202	.130	.072	.018	.001	1.00
" 11	8:00 AM	10	.09	6.4	.260	.192	.068	.020	.001	1.00
" 12	8:00 AM	9	.09	4.9	.208	.122	.086	.018	.001	0.95
" 13	8:00 AM	11	.05	4.4	.150	.088	.062	.034	.003	1.00
" 14	8:00 AM	8	.03	3.7	.146	.078	.068	.028	.002	0.80
" 15	9:30 AM	9	.03	3.5	.146	.064	.082	.026	.002	0.80
" 16	9:45 AM	10	.05	3.1	.130	.078	.052	.022	.002	1.00
" 17	10:30 AM	12	.04	3.0	.110	.060	.050	.008	.000	0.72
" 18	1:00 PM	13	.04	2.6	.108	.064	.042	.008	.001	0.76
" 20	10:00 AM	13	.04	4.5	.198	.138	.060	.022	.001	0.72
" 21	5:10 PM	13	.04	2.9	.110	.058	.052	.012	.004	0.60
" 22	10:05 AM	14	.04	3.0	.122	.056	.066	.020	.003	0.60
" 23	5:20 PM	14	.04	2.5	.116	.056	.060	.016	.001	0.64
" 25	11:40 AM	13	.04	6.2	.298	.224	.074	.026	.003	0.64
" 26	1:20 PM	18	.07	3.0	.128	.146	.072	.030	.004	0.64
" 27	4:00 PM	12	.03	3.8	.148	.076	.072	.018	.004	0.62
" 28	8:05 PM	13	.03	5.1	.236	.164	.072	.026	.003	0.58
" 29	10:30 AM	13	.08	5.8	.288	.210	.078	.028	.003	0.62
" 30	10:30 AM	14	.09	7.2	.386	.292	.094	.030	.002	0.54
May 2	2:35 PM	15	.10	7.6	.284	.192	.092	.018	.004	0.58
" 3	4:05 PM	15	.12	5.0	.196	.122	.074	.014	.004	0.62
" 5	4:45 PM	15	.10	4.3	.186	.110	.076	.016	.005	0.62
" 6	9:15 AM	14	.12	4.0	.176	.092	.084	.018	.005	0.62
" 7	3:15 PM	13	.14	6.9	.410	.318	.092	.028	.005	0.66
" 8	11:05 AM	12	.17	6.5	.362	.274	.088	.028	.005	0.74
" 9	2:20 PM	14	.14	6.4	.356	.268	.088	.024	.004	0.70
" 10	1:15 PM	14	.14	6.9	.302	.216	.086	.026	.003	0.70
" 11	4:30 PM	16	.09	5.6	.274	.192	.082	.018	.005	0.70
" 12	11:30 AM	16	.10	6.0	.290	.200	.090	.020	.005	0.70
" 13	3:15 PM	16	.14	5.8	.274	.196	.078	.016	.006	0.78
" 14	1:15 PM	16	.12	4.9	.210	.118	.092	.016	.002	0.70
" 16	12:00 M	18	.14	4.8	.248	.168	.080	.016	.004	0.78
" 17	10:35 AM	18	.15	4.4	.208	.112	.086	.018	.005	0.74
" 18	10:30 AM	19	.11	3.5	.176	.080	.096	.018	.004	0.66
" 19	4:10 AM	20	.12	4.6	.238	.140	.098	.018	.004	0.70

Analyses of Ohio River Water.

In Parts per Million.]

Chlorine.	Sulphuric Acid.	Incrusting Constituents.	Alkalinity.	Residue on Evaporation			Iron.	Carbonic Acid.	Dissolved Oxygen.	Bacteria per Cubic Centimeter.
				Dissolved.	Suspended	Total.				
4.5	47	....	33	117	534	651	21	....	....	24,900
5.5	39	26	38	129	505	634	16	27	8.0	12,200
9.5	37	25	33	130	443	573	26	24	7.8	15,200
5.0	36	27	32	127	307	434	15	11	8.8	9,700
3.0	27	11	30	111	334	445	19	8	9.3	13,500
4.0	26	20	26	129	140	269	13	....	....	14,300
4.0	24	36	33	119	126	245	8	6	9.8	8,800
4.0	26	36	29	114	118	232	7	....	....	27,600
5.0	22	37	30	101	182	283	10	....	....	14,100
5.5	26	42	30	92	152	244	8	11	9.2	6,900
5.5	28	30	37	120	155	275	11	13	10.0	7,200
5.5	21	37	34	114	312	426	11	16	....	7,900
5.5	28	30	26	113	283	396	11	25	....	6,600
5.0	26	38	37	101	158	259	7	24	....	3,200
4.0	26	35	37	102	390	492	16	24	....	4,400
6 0	27	35	42	111	164	275	9	....	....	5,600
6.0	34	32	42	112	191	303	13	38	....	4,800
6.0	31	32	46	110	154	264	7	35	....	5,200
6.0	32	57	37	108	194	302	15	23	6.7	6,900
7.0	35	38	43	139	97	236	5	29	....	4,400
7.0	31	38	45	115	91	206	4	34	....	3,700
8.0	30	48	43	132	115	247	6	34	....	6,000
8.0	31	38	42	122	86	208	5	....	....	6,500
8.0	32	42	48	109	101	210	5	27	....	12,700
8.0	27	39	46	103	251	354	11	30	7.4	12,500
6.0	28	37	42	101	67	168	4	29	....	12,800
8.0	31	38	46	110	77	187	4	29	....	14,900
8.0	32	43	41	118	75	193	3	....	....	14,900
8.0	29	43	46	135	251	386	8	33	....	20,800
7.0	29	40	48	125	58	183	3	34	....	15,000
8.0	18	36	46	132	72	204	4	34	9 5	12,400
8.0	24	46	40	135	223	358	8	27	....	21,400
12.5	24	43	47	133	290	423	10	28	....	15,000
8.0	21	48	36	114	446	560	14	24	....	13,500
8.0	21	39	37	121	274	395	13	17	....	8,200
7.0	21	37	38	116	122	238	4	12	....	5,600
7 0	21	37	45	117	137	254	4	17	8 6	4,100
7.0	21	36	51	118	147	265	2	20	....	4,600
6.0	21	40	49	113	419	532	15	31	....	33,000
6.0	20	51	46	122	312	434	13	....	....	54,600
6.0	18	33	48	116	305	421	13	26	....	16,800
6.0	16	33	42	112	312	424	14	22	....	1,000
5.0	14	28	37	113	207	320	10	19	7.6	6,800
6.0	13	20	42	111	250	361	11	22	....	6,600
6.5	15	44	51	112	216	328	9	15	....	14,500
7.0	18	32	53	114	122	236	7	26	....	6,400
8.0	21	56	63	123	179	302	7	13	....	6,900
8.0	21	50	66	122	133	255	7	22	....	7,500
6.0	13	48	41	117	99	216	5	24	7.9	7,400
6.0	19	40	42	135	171	306	8	27	....	7,900

Results of Chemical and Bacterial

[*Chemical Results Expressed*

Collected. Date.	Hour.	Temperature. Degrees Centigrade.	Color.	Oxygen Consumed.	Nitrogen as Albuminoid Ammonia. Total.	Suspended	Dissolved.	Free Ammonia.	Nitrites.	Nitrates.
1898										
May 20....	4:05 PM	20	.15	7.2	.330	.244	.086	.020	.003	0.66
" 21....	11:00 AM	19	.15	7.5	.358	.256	.102	.018	.003	0.66
" 22....	6:30 AM	20	.15	6.6	.356	.252	.104	.018	.003	0.66
" 23....	11:10 AM	21	.15	6.9	.362	.254	.108	.016	.003	0.70
" 24....	11:00 AM	21	.12	5.9	.276	.180	.096	.018	.005	0.70
" 25....	2:55 PM	21	.10	4.0	.174	.098	.076	.018	.002	0.61
" 26....	1:00 PM	21	.12	6.1	.298	.216	.082	.016	.003	0.61
" 27....	2:30 PM	22	.10	4.8	.242	.162	.080	.018	.003	0.61
" 28....	2:40 PM	22	.10	5.2	.230	.158	.082	.020	.003	0.61
" 29....	10:15 AM	21	.08	5.5	.252	.158	.094	.018	.004	0.57
" 30....	10:30 AM	21	.12	4.8	.212	.126	.086	.022	.004	0.57
" 31....	1:00 PM	22	.14	5.5	.300	.210	.090	.016	.003	0.57
June 1....	3:50 PM	23	.12	5.5	.258	.176	.082	.020	.002	0.61
" 2....	11:10 AM	23	.10	5.2	.266	.188	.078	.022	.003	0.57
" 3....	1:00 PM	24	.10	5.1	.242	.156	.086	.016	.003	0.53
" 4....	4:20 PM	24	.10	4.1	.218	.126	.092	.018	.003	0.61
" 6....	12:35 PM	25	.10	4.4	.216	.138	.078	.018	.003	0.57
" 7....	12:50 PM	25	.10	3.2	.186	.102	.084	.018	.002	0.57
" 9....	12:50 PM	26	.08	2.7	.148	.076	.072	.024	.003	0.41
" 10....	3:40 PM	27	.08	2.8	.188	.060	.078	.022	.004	0.49
" 13....	1:00 PM	28	.09	2.5	.166	.076	.090	.018	.002	0 41
" 15....	12:10 PM	27	.07	2.5	.148	.054	.094	.026	.002	0.41
" 16....	3:15 PM	27	.07	2.2	.134	.046	.088	.028	.002	0.45
" 18....	3:25 PM	28	.04	2.2	.146	.056	.090	.016	.003	0.41
" 19....	9:30 AM	27	.08	2.3	.174	.084	.090	.020	.003	0.45
" 20....	9:20 PM	27	.06	2.7	.194	.092	.102	.016	.002	0.45
" 24....	11:40 AM	25	.09	4.6	.212	.142	.070	.024	.004	0.49
" 24....	8:05 PM	26	.10	4.9	.248	.168	.080	.018	.001	0.61
" 25....	5:20 PM	26	.08	4.4	.196	.096	.100	.018	.001	0.57
" 28....	1:35 PM	28	.07	3.9	.208	.110	.098	.026	.002	0.57
" 29....	9:25 PM	27	.08	4.8	.228	.142	.086	.028	.004	0.61
" 30....	9:45 AM	25	.09	4.9	.252	.154	.098	.022	.003	0.61
July 1....	11:25 AM	26	.08	4.0	.242	.158	.084	.028	.003	0.65
" 2....	9:40 PM	28	.10	3.6	.184	.090	.094	.026	.002	0.65
" 4....	10:00 AM	28	.10	3.4	.190	.102	.088	.026	.001	0.57
" 7....	3:30 PM	28	.10	3.5	.178	.098	.080	.024	.002	0.61
" 8....	9:55 PM	27	.10	2.7	.144	.066	.078	.024	.002	0.53
" 9....	2:40 PM	28	.08	2.7	.184	.094	.090	.026	.002	0.53
" 10....	10:15 AM	25	.10	3.1	.144	.062	.082	.026	.002	0.41
" 13....	10:40 AM	25	.08	2 8	.150	.068	.082	.028	.003	0.41
" 14....	9:30 PM	26	.08	2.8	.144	.068	.076	.024	.003	0.41
" 16 ...	9:00 AM	26	.08	3 0	.144	.064	.080	.024	.003	0.41
" 18....	1:05 AM	26	.08	2.6	.152	.064	.088	.032	.003	0.45
" 19....	10:30 AM	27	.08	3.8	.254	.174	.080	.028	.003	0.49
" 20....	10:20 PM	27	.10	5.8	.308	.224	.084	.042	.007	0.45
" 22....	6:00 PM	28	.08	4.8	.270	.180	.090	.038	.007	0.57
" 23....	9:45 PM	26	.08	3.9	.240	.152	.088	.024	.006	0.57
" 25....	4:30 PM	28	.08	4.1	.240	.146	.094	.026	.003	0.61
" 27....	4:25 PM	29	.11	7.1	.524	.424	.100	.028	.005	0.61
" 28....	3:20 PM	28	.11	9.3	.624	.509	.116	.032	.007	0.57
" 29....	9:50 PM	27	.12	5.2	.258	.162	.096	.030	.007	0.53
Aug. 1....	10:20 PM	28	.12	5.3	.316	.226	.090	.028	.004	0.49
" 2....	4:10 PM	28	.11	5.3	.360	.266	.094	.026	.002	0.53
" 3....	10:35 AM	28	.15	5.0	.314	.214	.100	.018	.003	0.57
" 5....	2:35 PM	26	.08	5 6	.364	.264	.100	.024	.002	0.57
" 6....	1:00 PM	26	.11	5.8	.318	.216	.102	.024	.000	0.57

Analyses of Ohio River Water.

In Parts per Million.]

Chlorine.	Sulphuric Acid.	Incrusting Constituents.	Alkalinity.	Residue on Evaporation.			Iron.	Carbonic Acid.	Dissolved Oxygen.	Bacteria per Cubic Centimeter.
				Dissolved.	Suspended	Total.				
9.5	13	36	48	134	394	528	15	14	....	10,300
10.0	13	32	44	112	396	508	17	12	....	5,500
6.0	14	31	40	108	310	418	15	....	....	6,700
6.0	16	47	37	102	322	424	15	15	....	6,200
6.0	20	36	30	111	218	329	9	21	....	6,400
4.0	18	31	36	101	109	210	7	20	6.4	3,700
4.0	17	34	35	95	313	408	14	21	....	8,400
6.0	18	30	36	99	205	304	8	21	....	6,900
5.5	19	26	35	97	174	271	9	25	....	6,000
4.5	16	25	30	91	184	275	8	....	....	7,700
5.5	15	25	32	101	154	255	7	....	....	4,900
5.0	13	27	38	102	204	306	10	21	....	6,100
6.0	16	27	46	105	193	298	10	20	6.1	5,800
4.0	15	24	50	117	184	301	9	20	....	5,600
4.0	15	34	45	110	217	327	12	22	....	4,100
6.0	15	31	45	120	124	244	7	24	....	4,800
6.5	23	29	52	139	149	288	10	17	....	6,300
6.0	23	28	49	127	72	209	6	22	6.5	5,400
9.0	22	42	50	137	64	201	7	13	....	4,900
9.0	24	34	52	134	64	198	5	22	....	3,600
9.0	24	36	35	139	74	213	5	32	5.6	6,600
9 0	25	31	61	145	79	224	5	27	...	6,000
10 0	23	33	65	162	35	197	5	32	....	1,200
10.0	25	30	61	165	39	204	4	32	....	4,700
10.0	24	28	65	170	37	207	4	27	....	3,900
14.0	28	30	57	198	68	266	6	32	....	5,700
12.0	27	41	48	169	197	366	9	24	....	12,600
12.0	24	38	45	133	191	324	9	. ..	....	8,200
12 0	25	38	45	140	151	291	5	....	....	10,400
10.0	27	41	49	140	154	294	9	23	6.1	7,000
12.0	26	37	50	138	221	359	12	26	....	10,500
12.0	26	30	50	140	243	383	17	22	....	12,300
11.0	26	34	42	141	194	335	6	27	....	6,700
12.0	26	52	50	146	111	257	5	....	....	8,100
12 0	26	41	48	140	76	216	3	....	....	5.000
12 0	24	40	57	133	165	298	7	41	6.6	9,200
12.0	23	38	58	153	78	231	6	31	....	8,900
13.5	24	51	46	159	94	253	7	23	....	6,600
14.0	24	49	46	131	76	207	6	....	....	3,500
16.0	23	40	49	152	58	210	5	28	7.7	9,800
15.0	24	37	45	159	52	211	5	....	....	17,900
16.0	24	41	46	157	81	238	5	28	....	11,000
13.0	23	38	60	161	70	231	8	....	....	7,900
12.0	23	36	66	147	244	391	10	32	5.7	16,700
12.0	23	36	66	145	370	515	18	....	....	25,100
10.0	23	35	66	138	274	412	13	32	....	16,600
10.0	23	36	61	142	175	317	8	....	....	16,800
9.0	23	27	52	128	173	301	8	31	....	59,700
10.0	15	33	57	131	609	740	29	34	....	16,100
10.0	16	31	60	135	924	1,059	32	26	5.9	28 000
12.0	24	30	60	160	271	431	14	....	....	12,500
10 0	24	35	54	134	394	528	17	....	....	12,100
10.0	23	32	51	136	324	460	15	30	....	11,100
13.0	24	33	51	137	316	453	15	27	6.0	11,400
13.0	25	44	41	167	336	503	11	32	....	10,100
12.0	21	46	45	156	405	561	21	24	....	9,700

Results of Chemical and Bacterial

[*Chemical Results Expressed*

Collected.		Temperature. Degrees Centigrade.	Color.	Oxygen Consumed.	Nitrogen as					
					Albuminoid Ammonia.			Free Ammonia.	Nitrites.	Nitrates.
Date.	Hour.				Total.	Suspended	Dissolved.			
1898										
Aug. 7....	10:00 PM	27	.14	9.3	.560	.456	.104	.024	.000	0.57
" 9....	7:00 AM	25	.13	13.1	.820	.718	.102	.022	.000	0.57
" 10....	8:00 PM	24	.13	11.1	.580	.480	.100	.024	.001	0.53
" 12....	4:00 AM	24	.12	16.8	.860	.756	.104	.020	.006	0.61
" 13....	7:15 AM	23	.14	10 3	.490	.396	.094	.024	.000	0.53
" 15....	6:20 PM	24	.14	5.6	.230	.128	.102	.026	.001	0.53
" 16....	4:20 PM	24	.14	8.1	.396	.290	.106	.024	.000	0.53
" 18....	7:00 PM	25	.14	9.1	.590	.496	.094	.028	.001	0.61
" 19....	6:10 AM	24	.14	8.7	.430	.340	.090	.024	.000	0 57
" 20....	3:10 AM	24	.14	9.1	.390	.286	.104	.030	.001	0.57
" 22 ...	3:00 AM	26	.14	6.5	.286	.200	.086	.026	.000	0 53
" 23 ...	2:25 AM	26	.14	6.5	.264	.168	.096	.026	.000	0.53
" 24....	2:00 PM	26	.14	7.8	.450	.350	.100	.028	.000	0.57
" 27...	6:00 PM	25	.14	8.1	.474	.364	.110	.026	.001	0.57
" 30....	12:25 PM	26	.14	6.4	.268	.168	.100	.028	.000	0.57
" 31...	6:15 PM	27	.14	5.5	.218	.108	110	.024	.001	0.49
Sept. 2...	2:00 PM	28	.13	4.3	.198	.098	.100	.024	.001	0.57
" 3....	11:40 AM	27	.14	3.8	.178	.070	.108	.026	.001	0.57
" 5....	4:30 AM	26	.10	3.5	.184	.070	.114	.026	.000	0.45
" 9 ...	6:15 PM	24	.08	3.1	.194	.092	.102	.024	.002	0 41
" 10....	9:30 AM	23	.10	2.9	.180	.076	.104	.024	.002	0 41
" 10....	4:25 PM	24	.08	3.1	.190	.076	.114	.026	.002	0.41
" 13....	10:45 AM	23	.11	2.4	.190	.098	.092	.024	.001	0.45
" 14....	10:20 AM	22	.11	2.6	.146	.048	.098	.024	.003	0.45
" 15....	1:15 PM	23	.10	2.4	.140	.054	.086	.020	.002	0.45
" 16....	4:30 PM	23	.10	3.7	.210	.112	.098	.028	.003	0.49
" 17....	1:45 PM	23	.12	2.6	.144	.052	.092	.020	.001	0.41
" 18....	7:15 PM	24	.10	2.5	.124	.028	.096	.018	.001	0.41
" 21....	3:40 PM	23	.12	5.5	.312	.218	.094	.018	.001	0.45
" 22....	10:20 AM	23	.10	5.3	.292	.190	.102	.038	.030	0.49
" 23....	4:45 PM	23	.08	4.0	.226	.118	.110	.024	.003	0.45
" 26....	7:20 AM	23	.10	2.9	.174	.082	.092	.044	.003	0 49
" 27....	12:20 PM	23	.08	3.2	.222	.122	.100	.050	.005	0.49
" 29....	6:15 PM	24	.08	2.4	.142	.052	.090	.028	.003	0.45
Oct. 1....	1:10 PM	23	.11	2.2	.142	.058	.084	.018	.002	0.37
" 3....	8:50 PM	23	.09	1.8	.116	.050	.066	.024	.002	0.41
" 5....	1:50 PM	23	.08	2.5	.130	.056	.074	.036	.003	0.41
" 7....	1:40 PM	22	.08	2.0	.116	.046	.070	.038	.003	0.45
" 9....	11:05 AM	21	.08	2.0	.116	.044	.072	.036	.003	0.53
" 10....	4:50 PM	22	.12	2.9	.126	.048	.078	.018	.003	0.49
" 11....	6:30 PM	20	.10	2.2	.130	.038	.092	.042	.002	0.53
" 13....	6:30 PM	18	.08	2.6	.128	.052	.076	.032	.002	0 57
" 14....	2:00 PM	17	.10	2.8	.160	.054	.106	.018	.002	0.57
" 15....	9:45 AM	16	.08	2.3	.124	.032	.092	.026	.002	0.49
" 17....	6:30 PM	16	.08	3.1	.204	.126	.078	.018	.004	0 45
" 19....	2:35 AM	14	.07	2.1	.112	.042	.070	.028	.002	0.49
" 20....	6:00 AM	14	.07	1.8	.106	.034	.072	.042	.001	0.42
" 22....	5:00 AM	13	.07	1.9	.128	.022	.106	.026	.000	0.46
" 23 ...	12:40 AM	11	.11	2.6	.162	.052	.110	.026	.000	0.46
" 24....	6:30 PM	13	.07	4.4	.266	.184	.082	.028	.003	0.46
" 26....	6:30 PM	12	.08	10.9	.698	.606	.092	.026	.005	0.54
" 27....	10:30 PM	10	.08	8.4	.518	.422	.096	.020	.006	0.54
" 28....	6:50 PM	11	.08	7.3	.500	.424	.076	.032	.005	0.46

Analyses of Ohio River Water.

In Parts per Million.]

Chlorine.	Sulphuric Acid.	Incrusting Constituents.	Alkalinity.	Residue on Evaporation.			Iron.	Carbonic Acid.	Dissolved Oxygen.	Bacteria per Cubic Centimeter.
				Dissolved	Suspended	Total.				
15.0	28	44	44	159	867	1,026	26	....	....	13,100
8.0	23	41	37	117	1,255	1,372	39	....	....	32,500
8.0	24	38	37	118	800	913	30	....	....	28,100
7.0	22	38	34	105	1,321	1,426	28	20	3.9	10,800
3.0	22	36	20	73	641	714	22	....	....	5,900
3.0	22	42	20	67	182	249	12	9	....	5,400
5.0	24	43	27	90	379	469	20	18	6.3	4,000
5.0	24	33	42	101	681	782	31	....	....	15,100
5.0	24	30	36	83	504	587	20	16	....	22,000
4.0	23	28	32	95	533	628	17	....	....	19,900
5.0	23	30	34	99	277	376	11	16	....	5,500
4.0	24	37	35	100	267	367	11	....	....	5,700
6.0	25	34	37	111	537	648	22	20	5.9	6,000
8.0	22	37	32	118	429	547	17	....	....	9,300
8.0	23	43	40	116	205	321	10	19	5 8	4,500
7.0	23	41	36	114	138	252	8	....	....	6,200
6.0	23	50	39	117	82	199	5	12	....	5,900
6.0	26	48	36	122	75	197	6	13	....	7,200
6.0	22	47	39	123	69	192	6	....	....	5,600
12.0	23	43	45	137	39	176	4	20	7.9	11,100
12.5	24	43	46	134	29	163	4	. ..	....	6,800
13.5		41	41	128	46	174	4	....	....	6.800
10.0	23	43	37	121	57	178	5	28	7.8	8,200
10.0		43	35	141	28	169	4	23	....	14,800
11.0		47	41	145	36	181	7	....	....	10,100
13.0	21	42	44	144	130	274	6	. ..	....	8,400
13.5		42	47	147	42	189	3	....	....	12,400
16.0		47	42	147	28	175	3	....	....	21,600
24.0	16	43	49	178	241	419	10	37	7.6	21,000
21.0		42	54	189	257	446	9	....	....	26,900
19.0	27	50	42	196	133	329	7	....	....	15,600
17.0		46	51	177	81	258	6	....	....	15.500
16.0	30	44	45	179	117	296	5	....	....	27,800
21.0		47	54	199	69	268	4	31	7.6	11,200
11.0	18	40	50	137	40	177	5	....	....	13,000
13.0		37	52	145	32	177	4	....	....	31,500
9.0	16	43	55	154	48	202	6	....	....	34.400
10.0		45	57	153	39	192	5	47	7.0	27,000
14.0		44	62	189	27	216	4	....	. ..	14,000
12.0	19	43	57	186	51	237	4	....	....	9,800
24.0		55	59	204	63	267	6	....	....	16,000
14 0		45	50	139	46	185	8	....	....	5,300
11.0	23	48	47	138	60	198	7	19	6.3	7,300
11.0		30	52	140	24	164	5	....	....	5,200
15.0		37	61	152	38	190	3	....	....	105,000
16.0	23	36	56	162	40	202	4	....	....	7,100
16.0		48	52	150	41	191	3	....	....	5,400
33.0	27	21	58	204	35	239	5	....	....	4,700
44.0		23	55	223	55	278	5	....	....	5,200
20.0		31	48	169	144	313	20	26	7.0	7.000
14.0	26	25	25	105	599	704	52	....	....	23,800
20.0		36	25	133	414	547	28	....	....	19,800
15.0	29	36	32	144	369	513	22	....	....	16,800

Results of Chemical aud Bacterial

[*Chemical Results Expressed*

Collected.			Temperature. Degrees Centigrade.	Color.	Oxygen Consumed.	Nitrogen as					
						Albuminoid Ammonia.			Free Ammonia.	Nitrites.	Nitrates.
Date.		Hour.				Total.	Suspended	Dissolved.			
1898											
Oct.	30....	11:30 PM	9	.10	7.4	.390	.298	.092	.020	.005	0.50
Nov.	1....	4:00 AM	8	.12	8.1	.466	.364	.102	.020	.002	0.66
"	2....	4:00 AM	9	.12	6.7	.358	.256	.102	.020	.003	0.66
"	4....	3:20 AM	9	.14	6.0	.308	.210	.098	.024	.002	0.62
"	4....	1:15 PM	10	.15	5.7	.266	.164	.102	.026	.002	0.58
"	7....	9:00 AM	9	.15	4.9	.236	.138	.098	.024	.000	0.62
"	8 ...	11:40 AM	9	.15	5.3	.224	.130	.094	.026	.000	0.66
"	8....	6:30 PM	9	.15	5.3	.232	.126	.106	.024	.003	0.62
"	10....	6:30 PM	9	.18	8.4	.552	.442	.110	.020	.004	0.78
"	11....	9:00 PM	9	.22	9.7	.484	.384	.100	.020	.004	1.18
"	12....	7:15 AM	8	.12	6.5	.468	.366	.102	.022	.004	0.94
"	16..	10:30 AM	8	.20	8.2	.472	.364	.108	.024	.004	1.02
"	16....	2:20 PM	9	.20	8.2	.424	.322	.102	.022	.003	1.06
"	17....	3:00 AM	8	.18	8.1	.436	.328	.108	.024	.004	1.06
"	19....	10:00 AM	7	.18	6.9	.340	.236	.104	.022	.001	1.06
"	20....	1:50 PM	7	.17	6.6	.286	.178	.108	.022	.002	1.10
"	21....	6:45 PM	9	.19	7.1	.318	.220	.098	.024	.001	1.02
"	24....	9:30 AM	5	.17	5.1	.236	.128	.108	.018	.001	0.90
"	26....	11:10 AM	5	.20	4.0	.188	.098	.090	.024	.002	0.70
"	28....	1:50 PM	5	.15	3.8	.160	.084	.076	.020	.001	0.66
"	30....	11:10 AM	5	.10	3.7	.168	.078	.090	.028	.005	0.82
Dec.	2....	2:20 AM	5	.08	3.2	.128	.040	.088	.024	.005	0.78
"	3....	8:00 PM	3	.10	3.2	.112	.032	.080	.026	.002	0.78
"	6....	8:20 PM	1	.15	8.0	.446	.348	.098	.028	.004	0.78
"	8....	6:30 PM	1	.15	4.9	.240	.156	.084	.030	.006	0.82
"	10....	9:15 AM	2	.10	5.2	.322	.226	.096	.030	.002	0.82
"	13....	3:20 AM	1	.08	3.3	.184	.082	.102	.032	.003	0 90
"	15....	4:50 PM	1	.10	2.5	.122	.042	.080	.048	.005	0 90
"	17....	9:45 AM	1	.08	2.7	.102	.026	.076	.042	.005	0.94
"	20....	4:00 AM	2	.14	13.3	.868	.758	.110	.074	.004	1.10
"	20....	11:00 AM	1	.12	12.6	.846	.720	.126	.068	.012	1.18
"	21....	9:00 PM	3	.12	6.9	.372	.228	.144	.044	.004	1.34
"	24....	9:00 AM	1	.10	6.3	.348	.246	.102	.056	.002	1.18
"	27....	4:10 PM	1	.08	7.3	.426	.312	.114	.054	.004	1.26
"	29....	6:45 PM	4	.10	5.4	.244	.154	.090	.030	.002	1.10
"	31....	2:00 PM	2	.12	7.0	.548	.468	.080	.016	.004	1.06
1899											
Jan.	5*...	7:30 AM	3	.10	3.7	.224	.128	.096	.026	.001	1.10
"	7†..	8:00 AM	4	.11	5.8	.330	.226	.104	.022	.001	1.14
"	5‡...	12:20 PM	4	.11	8.0	.526	.418	.108	.018	.001	1.10
"	7ǧ...	12:15 PM	2	.07	4.9	.228	.108	.120	.022	.003	0.98
"	8....	1:00 PM	3	.10	11.4	.546	.398	.148	.028	.003	1.02
"	10....	11:40 AM	3	.10	8.6	.386	.314	.072	.016	.002	1.14
"	11....	3:45 AM	2	.10	8.7	.394	.312	.082	.022	.008	1.10
"	14 ...	12:10 AM	3	.12	11.8	.830	.726	.104	.022	.004	1.06
"	17....	8:15 AM	4	.15	9.6	.484	.400	.084	.014	.001	0.98
"	20....	7:40 AM	3	.12	7.7	.488	.400	.088	.024	.003	1.18
"	23...	8:00 AM	3	.13	5.1	.254	.166	.088	.008	.003	1.18

* Lot 202. † Lot 203. ‡ Lot 204. ǧ Lot 205.

Analyses of Ohio River Water.

In Parts per Million.]

Chlorine.	Sulphuric Acid.	Incrusting Constituents.	Alkalinity.	Residue on Evaporation.			Iron.	Carbonic Acid.	Dissolved Oxygen.	Bacteria per Cubic Centimeter.
				Dissolved.	Suspended	Total.				
10.0		32	21	125	215	340	12	....	....	11,200
9.5	22	24	36	116	334	450	18	20	6.8	15,300
11.0		27	37	118	180	298	12	....	....	14,200
9.5		20	39	119	109	228	7	....	....	6,900
9.5		24	38	96	131	227	9	....	....	6,400
7.5	23	22	48	103	118	221	6	....	....	21,000
10.0		19	46	119	84	203	7	....	....	24,800
9.0		16	47	109	156	265	7	....	....	25,300
7.5		17	49	110	506	616	20	....	....	111,000
5 5	29	14	70	143	426	569	12	34	6.9	126,000
8.0		17	57	139	306	445	9	....	....	29,100
7.5	23	15	41	126	396	522	15	32	7.3	30,700
8.0		17	44	132	392	524	11	....	....	33,900
10.0		18	40	128	281	409	11	....	....	29,300
7.0	22	23	32	101	187	288	12	....	....	14,000
6.0		21	33	102	209	311	9	....	....	21,400
7.0	22	20	35	94	181	275	9	....	....	11,200
7.0		19	33	84	157	241	11	....	....	11,900
7.5	24	19	34	93	101	194	6	....	....	8,200
7.5		20	35	92	98	190	6	....	....	7,200
7.0	24	21	37	124	94	218	7	....	.. .	8,700
9.0		19	38	115	112	227	5	....	....	6,300
8.5	24	21	42	109	50	159	5	....	....	7,600
8.0		21	57	123	455	578	9	. ..	..	144,300
7.0	25	25	48	114	205	319	13	42	8.5	52,900
13.0		27	42	133	247	380	7	....	....	34,200
9.5	25	21	46	108	111	219	6	....	....	24,700
14.0		22	47	146	37	183	5	....	....	14.600
11.5	23	23	49	151	31	182	5	....	....	13,400
7.0	25	17	62	154	1,130	1,284	49	42	....	51,300
6.5		11	58	141	927	1,068	40	....	....	46,800
7.0		12	61	147	295	442	13	....	....	89,000
11.0	26	25	47	129	311	440	16	38	....	34,200
8.0		28	36	113	374	487	20	....	....	37,500
6.0	24	17	28	97	170	267	8	....	....	25,800
6.0		16	43	114	301	415	14	....	.. .	31,000
6.0	24	16	46	114	80	194	5	....	....	18.700
6.5		17	47	118	256	374	10	....	...	27,700
6.5	26	18	43	112	434	546	15	....	....	42,200
7.0		16	44	107	159	266	7	....	....	14,600
7.5	23	17	26	120	681	801	30	....	....	33,800
5.0		15	22	75	383	458	18	....	....	21,000
7.0		19	24	80	419	499	18	....	....	22,300
3.0	17	18	33	90	863	953	28	....	. ..	31,700
4.0		19	27	86	500	586	20	....	....	38 400
7.5	23	24	31	103	418	521	20	....	....	32,500
6 0		16	35	90	174	264	11	....	....	18,900

BIOLOGICAL CHARACTER OF THE RIVER WATER.

On each sample of river water, corresponding to each tankful of subsided water, there were determined the number of bacteria present in the water, and also the presence or absence of bacillus coli communis.

Quantitative Bacterial Results.

The quantitative bacterial results, as a matter of convenience, have been given in the foregoing tables of regular chemical results, and are the average of two samples collected five minutes apart.

Bacillus Coli Communis.

Concerning bacillus coli communis there is little room for doubt that it was constantly present in the river water from the present intake. From the evidence at hand it is probable that, by taking two cubic centimeters for each test, this germ would be found practically without exception. Upon taking one cubic centimeter for each test, the identity of this bacillus was established in 60 per cent of the samples, as shown by the results of tests as follows:

Table Showing the Results of Tests (Positive or Negative) for Bacillus coli communis in the Ohio River Water at Cincinnati.

Date.	Result.	Date.	Result.	Date.	Result.	Date.	Result.
1898.		1898.		1898.		1898.	
March 24..	—	May 18..	—	July 23..	+	Oct. 7..	—
" 25..	—	" 19..	+	" 25..	—	" 9..	+
" 26..	—	" 20..	—	" 27..	—	" 10..	+
" 29..	+	" 21..	—	" 28..	+	" 11..	+
" 31..	+	" 22..	—	" 29..	+	" 13..	+
		" 23..	+			" 14..	—
April 1..	—	" 24..	+	Aug. 1..	+	" 15..	+
" 2..	—	" 25..	—	" 2..	—	" 17..	—
" 3..	—	" 26..	+	" 3..	+	" 19..	—
" 4..	—	" 27..	+	" 5..	+	" 20..	—
" 5..	+	" 28..	+	" 6..	+	" 22..	—
" 6..	+	" 29..	—	" 7..	+	" 23..	—
" 7..	—	" 30..	—	" 9..	—	" 24..	+
" 8..	+	" 31..	+	" 10..	+	" 26..	+
" 9..	+			" 12..	+	" 27..	+
" 10..	—	June 1..	—	" 13..	+	" 28..	+
" 11..	—	" 2..	—	" 15..	+	" 30..	+
" 12.	—	" 3..	+	" 16..	+		
" 13..	+	" 4..	—	" 18..	+	Nov. 1..	+
" 14..	—	" 6..	+	" 19..	+	" 2..	+
" 15..	+	" 7..	+	" 20..	+	" 4..	+
" 16..	+	" 9..	—	" 22..	—	" 7..	+
" 17..	—	" 10..	—	" 23..	—	" 8..	+
" 18..	+	" 13..	—	" 24..	+	" 10..	—
" 20..	+	" 15..	+	" 27..	+	" 11..	—
" 21..	—	" 16..	+	" 30..	—	" 12..	—
" 22..	+	" 18..	—	" 31..	+	" 16..	—
" 23..	+	" 19..	+			" 17..	+
" 25..	+	" 20..	+	Sept. 2..	+	" 19..	—
" 26..	—	" 24..	+	" 3..	+	" 20..	—
" 27..	—	" 25..	+	" 5..	—	" 21..	—
" 28..	—	" 28..	+	" 9..	+	" 24..	—
" 29..	+	" 29..	—	" 10..	—	" 26..	+
" 30..	+	" 30..	+	" 13..	+	" 28..	—
				" 14..	—	" 30..	—
May 2..	+	July 1..	+	" 15 .	—		
" 3..	+	" 2..	+	" 16..	+	Dec. 2..	—
" 5..	+	" 4..	+	" 17..	+	" 3..	—
" 6..	+	" 7..	+	" 18..	—	" 6..	—
" 7..	—	" 8..	+	" 21..	—	" 8..	+
" 8..	—	" 9..	+	" 22..	+	" 10..	—
" 9..	+	" 10..	+	" 23..	+	" 13..	+
" 10..	+	" 13..	+	" 26..	+	" 15..	+
" 11..	+	" 14..	+	" 27..	+	" 17..	+
" 12..	+	" 16..	+	" 29..	+	" 20..	+
" 13..	—	" 18..	+			" 21..	+
" 14..	+	" 19..	+	Oct. 1...	+	" 24..	+
" 16..	+	" 20..	+	" 3...	—	" 27..	—
" 17..	+	" 22..	—	" 5..	+	" 29..	—

Disease Germs.

No special effort was made to isolate the germ of typhoid fever and other diseases, owing to the great uncertainty which is associated with the reliability of the results of current methods for their identification.

Microscopical Examinations.

For the greater part of the time the turbidity of the river water is so great that the algæ, diatoms, and other micro-organisms are so few as to be of very little practical significance. At times when the water in the river is fairly clear, however, these organisms become quite plentiful. The results of three examinations as follows are illustrative of the number and kinds of organisms found under these conditions.

Table Showing the Results of Microscopical Analyses of the Ohio River Water (Organisms per Cubic Centimeter).

	Serial Number of Sample.		
	1364.	3335.	7235.
Diatomaceæ—	April 28.	June 15.	October 17.
Asterionella	5.0	3.0	1.0
Cyclotella	0.5	0.5	0.5
Fragilaria	0.0	1.0	0.0
Melosira	0.0	1.0	0.0
Nitzschia	1.5	1.0	2.0
Pleurosigma	0.0	0.5	0.5
Synedra	4.5	4.0	6.0
Tabellaria	0.0	1.5	0.0
Chlorophyceæ—			
Arthrodesmus	0.5	0.5	0.0
Closterium	0.5	0.0	0.0
Conferva	0.5	1.5	1.0
Dictyosphærium	0.0	0.0	0.5
Oscillaria	0.0	1.0	0.0
Pediastrum	0.0	1.0	1.0
Protococcus	0.5	0.0	0.0
Raphidium	1.5	2.0	1.5

Microscopical Analyses—Concluded.

	Serial Number of Sample.		
	1364.	3335.	7235.
	April 28.	June 15.	October 17.
Chlorophyceæ—			
Rizoclonium	0.0	1.0	0.0
Scenedesmus	0.0	1.5	5.5
Spirogyra	0.0	2.0	0.0
Ulothrix	2.0	5.0	4.0
Fungi—			
Crenothrix	0.0	1.0	0.0
Moulds	0 0	2.5	1.0
Infusoria—			
Dinobryon	0.0	0.5	0.0
Glenodinium	1.0	0.0	0.0
Monas	0.0	1 0	1.5
Paramoecium	0.0	0.5	1.0
Synura	2.0	0.0	0.0
Trachelomonas	0.0	0.0	1.0
Rotifera—			
Anurea	0.0	0.5	0.0
Polyarthra	0.0	1.5	0.0
Rotifera	1.0	1.0	1.0
Synchæta	0.0	0.5	0.0
Crustaceæ—Daphnia	0.0	0.5	0.0
Miscellaneous—			
Ova	0.0	1.0	0.0
Scales	0.0	1.0	0.0
Total number	21.0	39.5	29.0

Amorphous matter very abundant.

Bacterial Flora of the River Water.

This subject is too broad to allow the completion of an exhaustive study under the conditions which existed with reference to methods, time, and pressure of other lines of work. Nevertheless, a considerable portion of the efforts of the biological department were directed to this field; and it is believed that reasonably satisfactory progress was made, especially in comparing the species of bacteria in the influent and effluent of the purification system, and portions thereof.

In the course of these comparative studies representative cultures of the river water bacteria were taken on June 23,

August 30, and November 7. In all 200 cultures of bacteria were studied in detail, and it was found that this number represented 42 different species according to the best information available upon the subject. A tabular statement of the leading differential characteristics of these species will be presented in a special paper already referred to under Methods of Analysis.

The following list includes those bacteria with which those found in the river water were identical, or to which they were similar to a marked degree:

Bacillus—aerogenes, Escherich.
" annulatus, Wright.
" antenniformis, Ravenel.
" aquatilis communis, Zimmerman.
" aquatilis sulcatus I, Weichelbaum.
" aquatilis sulcatus V, Weichelbaum.
" arborescens, Frankland.
" aurantiacus, Frankland.
" aurescens, Ravenel.
" candicans, Frankland.
" cereus, Frankland.
" cloacæ, Jordan.
" coli communis, Escherich.
" desidiosus, Wright.
" flavescens, Pohl.
" flexuosus, Wright.
" fluorescens incognitus, Wright.
" fluorescens ovalis, Ravenel, Wright.
" fluorescens liquifaciens, Flügge.
" fluorescens non liquifaciens, Eisenberg.
" fulvus, Zimmerman.
" fuscus, Zimmerman.
" geniculatus, Wright.

Bacillus—janthinus, Zopf.
" lactis erythrogenes, Hueppe.
" liquidus, Frankland.
" liquifaciens, Eisenberg.
" mesentericus vulgatus, Eisenberg.
" mycoides, Flügge.
" ocraceus, Zimmerman.
" prodigiosus, Ehrenberg.
" proteus Fluorescens, Jäger.
" pyocyaneus, Gessard.
" rubidus, Eisenberg.
" similtyphus, Eberth.
" solitarius, Ravenel.
" subflavus, Zimmerman.
" subtilis, Ehrenberg.
" superficialis, Jordan.
" violaceus, Frankland.
" viridis, Lesage.
Sarcina lutea, Schroeter.
Cladothrix dichotoma, Cohn.

CHAPTER II.

DESCRIPTION OF THE EXPERIMENTAL PURIFICATION PLANT.

LOCATION.

The experimental purification plant was located on city property, on the side of the hill below and adjoining the retaining wall of the Eden Park reservoir, as shown on Plate I. It was necessary, according to instructions of the Board of Trustees, to locate the plant on city property where unsubsided water could be obtained without secondary pumping, and so that the water should be passed through the subsiding basins and filters and finally discharged into the low-service system of the city, maintaining a gravity flow throughout. The only available way of conforming to these instructions was to locate the plant on the hillside above mentioned, and erect the subsiding basins and filters at such elevations that the former could be filled from the force main leading from the Front Street Pumping Station to the reservoir, and so that the filtered water could be discharged into the Third Street service line. At the Eden Park reservoir the elevation of the discharge of the force main is 248.73, and the maximum water level in the Third Street reservoir is at elevation 173.72. As the level of the water in the Third Street reservoir was seldom at the maximum, and as the normal consumption along Third Street reduced the pressure in the service line somewhat, there was rather more difference in level available than the above figures indicate.

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But as these reductions could not be counted upon, it was necessary to locate the plant between these two elevations.

In a straight line the distance from the experimental plant to the river was about 1,000 feet. River water was supplied through the 36-inch force main from the Front Street Pumping Station. From the river to the point where a 6-inch supply pipe for the plant was connected to the force main was 3,700 feet, and from this point to the discharge of the main into the Eden Park reservoir was 400 feet.

GENERAL ARRANGEMENT OF PLANT.

The general arrangement of the plant and of the main lines of the piping system is shown on Plate I. It will be seen that there were three main sections of the plant:

1. The four steel tanks in which subsidence of the river water took place.
2. The filters.
3. The laboratory.

The general arrangement and relative location of these parts will first be presented, and a detailed description of the individual parts of the several purification systems will then be given.

Subsiding Tanks.

For the purpose of subsidence there were provided four large steel tanks, each holding one day's supply for the original English filters, or 100,000 gallons. These tanks were located so that they could be filled from the force main, and a 6-inch supply pipe about 100 feet long was connected to each of them. The elevation of the platform which supported these tanks was 200.00, or 48.73 feet below the discharge into the Eden Park reservoir. The tops of the tanks were at an elevation of

234.25. From each of these tanks a 6-inch pipe led to the sewer about 140 feet distant where it discharged at an elevation of 175.32. Pipes were connected to the tanks at three different points on the side of each, and which in turn were connected together and led in one line to the filters where a regulating tank was provided. From the subsiding tank platform to the filter platform the distance was about 50 feet.

Filters and Filter Platform.

For supporting the filters there was provided a foundation and platform on which all the filters rested. On Plate II is given the general arrangement of the filter platform. The floor of this platform was at an elevation of 184.00, or 10.28 feet above the high water level in the Third Street reservoir, and 19.25 feet below the minimum flow line in the subsiding tanks. Fifteen wooden tanks, each located on separate crib work, were provided for the original English filters. The tops of these filters were on the same level, 10 feet above the platform.

Inlets.—As will be seen from Plate II, water from the subsiding tanks was discharged into a small regulating tank located at the south end of, and 10 feet above, the platform. By means of regulating valves the level of the water in this tank was kept practically constant. From the regulating tank to the several filters a system of large branching pipes was provided for the supply system. As the regulating tank and the tops of the filters were at the same elevation, the water in the regulating tank kept a practically uniform water level in all the filters, the inlet valves of which were normally wide open.

Outlets.—From the filters separate outlet pipes led to a meter room at the south end and below the platform. In this room all the meters were placed and the filtered water after

passage through the meters discharged into a wooden trough in this room. This trough, the bottom of which was at elevation 178.00, was connected at the bottom by a 6-inch pipe to the Third Street service line. A connection from this trough to the sewer was also provided, the overflow into the sewer being 4 inches above the outlet to the Third Street line. It was only at times of repairs in the Third Street line or in the pipe connecting to it that use was made of the sewer connection.

Gages.—On all of the outlet pipes at the meter room glass tube pressure gages were provided. These tubes extended through the platform and up to above the level of the top of the filters. Up to June, 1898, it was possible to correct gage readings obtained in this way by comparison with direct readings on the tanks about twice a month. It was found in the early part of June that corrosion and incrustation in the outlet pipes were causing a rapid and irregular increase in the friction loss in the outlet pipes. Glass gages were therefore placed on each filter, one just above the bottom (in the under drains) and the other just above the sand layer.

Rooms.—In order to protect the gages and the regulating tank from freezing, an irregularly shaped room, known as the gage room, was enclosed at the south end of the platform, and for the same reason a room 10 feet by 19 feet was enclosed below the platform, known as the meter room.

Roof.—The entire platform was covered by a roof as a protection to attendants, etc., it having been assumed from experience at other points that, with the turbid water which it would be necessary to filter, no difficulties would arise in the operation of these filters due to growths of algæ. The sides of the platform were all open.

Re-arrangements for the Modified English System.

The only marked re-arrangements and additions necessary for this system consisted in the conversion of the tank used as filter No. 15 into a subsiding tank, and in a small tower extension of the gage room to provide enclosed space for the chemical appliances.

Re-arrangements for the American System.

For the American system the tanks originally used as filters Nos. 3, 5, and 8 were converted into subsiding basins F, G, and H, and the tank used as filter No. 2 was elevated to 12.75 feet above the platform, for use as a wash water supply tank. The filter used in this system (No. 20) was located beneath the wash water supply tank, and its top was 8.33 feet above the platform. As described beyond, some re-arrangement of the chemical devices was also made. In order to protect the attendants, and to prevent difficulties from freezing, the gage room was extended to form a room about 20 feet square, in which were the main regulating tank, the chemical devices, the wash water supply tank, and filter No. 20.

All of these devices are taken up and described in order beyond.

Laboratory.

A well-lighted wooden building was erected for use as an office and laboratory. The general plan of this building is shown on Plate III. Steam was obtained from a 7 h. p. boiler and gas was furnished by the Gas Company. Connection was made to the high-service line for the water supply for the laboratory.

Elevations.

The relative elevations of the several leading parts of the plant are tabulated below, referred to a plane 1.75 feet above the zero of the waterworks gage as the datum plane.

PORTION OF PLANT.	ELEVATION.
Outlet of force main at Eden Park reservoir	248.73
Tops of subsiding tanks	234.25
Water level in subsiding tanks when filled for an available supply of 100,000 gallons	230.55
Minimum flow line in subsiding tanks	203.25
Bottom of subsiding tanks	200.25
Top of subsiding tank platform	200.00
Top of filter platform	184.00
Tops of filter tanks (English filters) and top of regulating tank	194.34
Top of filter No. 20	192.33
Maximum water level in wash water supply tank	202.00
Minimum water level in wash water supply tank	196.45
Outlets of filters in meter room	179.00
Bottom of filtered water trough (discharge to Third Street)	177.02
Maximum water level in Third Street reservoir	173.72
Discharge into sewer (drain from subsiding tanks and overflow from filtered water trough)	175.00
Discharge from chemical feed tank	198.50
Floor of laboratory	215.00

DESCRIPTION OF SUBSIDING TANKS A, B, C, AND D.

For the purpose of preliminary plain subsidence of the river water before its passage on to the filters, four large steel tanks were provided. Preliminary consideration led to the assumption at the beginning of the experimental work that three days (72 hours) was the probable economical maximum period of subsidence under the existing conditions. It was, however, deemed advisable to consider the effect of shorter periods, and during the latter part of the tests considerable attention was devoted to the relative efficiency of two and three days subsidence. In order to provide storage for sufficient water to allow of three days' plain subsidence, four steel tanks, each

holding one day's supply for the filters (100,000 gallons), were constructed. They were all of the same size and design, and were supported by a wooden platform on a pile foundation at elevation 200.00. The details of construction of these tanks are shown on Plate IV.

Size.—Each tank was 25 feet in diameter and 34 feet deep, inside measurements. The lowest outlet valve was 3.5 feet above the bottom, and from the plane of the center of this valve to the top of the tank the contents were 112,000 gallons. At a depth of 30.75 feet the available contents were 100,000 gallons.

Construction.—High grade steel plates were used in the construction of the tanks, which rested upon a bed of sand 1.75 inches thick laid on the foundation platform. The bottom of the tanks was level and the sides vertical. No baffle walls or partitions of any kind were provided. Each tank was made of seven rings. The bottom ring was made of plates 0.3125 inch thick, and all other rings of plates 0.25 inch thick. All of the horizontal joints and the vertical joints of the upper four rings were single riveted. The vertical joints of the lower three rings were double riveted. The bottom was made of plates 0.3125 inch thick with single riveted joints. It was connected with the sides by a 3 by 3 by 0.5-inch angle iron on the outside of the tank. The upper edge of the top ring was stiffened by a 3 by 3 by 0.375-inch angle iron on the outside. All rivets were 0.625 inch in diameter and made of select steel.

Piping Connections.—There were provided in each tank four openings with flange connections for 6-inch iron pipe, one in the bottom and three on the sides on a line vertically distant from the bottom 3, 13, and 23 feet, respectively. The opening in the bottom was 9.83 feet distant from the center of the tank,

and served as an inlet for the river water and an outlet for the purpose of draining to the sewer. At the end of this pipe there was provided a brass ball plug operated by a lever and hand chain, to serve as an emergency valve in the case of an accidental break in the pipe below the tank. The three openings in the side of the tank were connected to a single line of 6-inch cast iron pipe, as described above, and these pipes from all four tanks connected in one line through which the subsided water was conveyed to the filters.

Gage.—To observe the depth of the water in the tank, a small float inclosed in a wooden pipe was provided. This float was connected by a chain which passed over a wheel on the top of the tank, with an indicator on the outside of the tank. A suitably marked gage was provided alongside the guide through which the indicator traveled.

Ladders.—Each tank was provided with an iron ladder inside and outside, the two connecting at the top of the tank. These ladders were so located that the valves on the side connections could be readily operated from the outside ladder.

DESCRIPTION OF THE ENGLISH FILTERS.

All of the filters of the English type consisted of three main parts—a wooden tank, a system of gravel underdrains, and a layer of sand. There were also provided suitable piping connections, gages, etc. A typical section of one of these filters is shown on Plate V.

Wooden Tanks.—Each of the tanks, of which there were fifteen, was 11.78 feet in diameter on the inside. Three of the tanks were 6 feet deep, nine of them were 8 feet deep, and three were 10 feet deep, inside measurements. They were all made of select cypress 2 inches thick. The staves of these tanks were grooved on the inside face with horizontal half round

grooves 1.25 inches in diameter and 0.625 inch deep, spaced 6 inches from center to center, and in every instance the first groove was 12 inches above the bottom of the tank. There was one groove in the tanks 6 feet deep, five grooves in the 8-foot tanks, and nine grooves in the 10-foot tanks. The bottoms of all the tanks were level and the sides were practically vertical.

The tanks were bound with iron hoops of No. 10 B. W. G. (0.134 inch thick). On the 10-foot tanks there were five hoops 3 inches wide, and five hoops 2.5 inches wide. The 8-foot tanks had three 3-inch and five 2.5-inch hoops, and the 6-foot tanks two 3-inch and five 2.5-inch hoops. All hoops were provided with two adjusting lugs. In each tank above the underdrains and sand layer there was an open compartment 4.7 feet deep, which contained the water to be filtered. Normally the water in this compartment was from 4 to 4.5 feet deep, and the depth increased as the sand layers were scraped.

Piping Connections.—The inlet for each tank was a 1.5-inch iron pipe connected with the tank at the side 57 inches below the top and just above the surface of the sand layer. From the bottom of each tank a 1.5-inch pipe connected with the two other tanks in the same east and west row for the purpose of refilling after scraping, and another 1.5-inch pipe, which served as the outlet, led to the meter room, as described in preceding pages.

Gages.—As described above, up to June, glass gages on the outlet pipes at the meters were used. The irregular and rapidly increasing friction loss in the outlet pipes made frequent corrections necessary, however, and these gages were replaced early in June by glass tubes on the filters themselves. The lower one of these tubes measured the pressure in the underdrains, and the upper one the pressure at the surface of the

sand layer. Loss of head was obtained by difference. During the cold weather of the winter of 1898–99 it was necessary to remove these gages immediately after reading them.

Underdrains.

On the bottom of each tank there was laid a series of gravel layers to form a support for the sand layer, which was the filtering medium. These gravel layers not only supported the sand, but formed a more or less open space beneath the filtering medium through which the water could pass from different points on the bottom of the filter to the outlet pipe, which, as described above, was located at one side of the tank and was flush with the bottom. The bottom of the tanks and the top of the underdrains were in all cases horizontal planes. In order that there should be practically no difference in the rate of flow of the water through different parts of the sand layer, it was necessary to construct this system of underdrains so that there should be very little resistance to the passage of water from any point on the bottom of the sand layer to the outlet pipe. This was accomplished in accordance with recent American practice as follows:

It was estimated that in order to have the resistance of the underdrains less than one per cent of the resistance of the 3-foot coarse sand filter operating at the low rate (this filter having the lowest frictional resistance), a layer of gravel of about 0.5 inch average diameter (10.0 m.m. effective size) and 0.8 inch thick would be required. As gravel of this size as well as the sand above it would pass into the outlet pipes of the experimental filters, and in practice into the carrier pipes, the underdrains were constructed of successive layers of graded gravel, making each one as thin as practicable and grading

from 1.5-inch stones up to a suitable size to support the main sand layer.

Generally speaking, a layer of gravel will remain on top of the supporting layer providing it contains substantially no particles less than one third the size of the material on which it rests. Working on this principle, the following layers were put into the filters, all material being spread by a shovel from the top of the tanks, and then each layer was arranged by hand when necessary.

1. Coarse stones, from 1 to 2 inches in average diameter, 1.33 inches thick.
2. Walnut gravel—thickness of layer 0.75 inch.
3. Pea gravel—thickness of layer 0.75 inch.
4. Buckshot gravel—thickness of layer 0.60 inch.
5. Mortar sand—thickness of layer 1.20 inches.

Total thickness of underdrains, 4.63 inches.

All of these materials were pumped from the Ohio River on February 7, 1898, at a stage of 14.7 feet. They were screened dry on the barge, all of the intermediate sizes requiring double screening. Owing to freezing of some sand in the gravel and the presence of some wooden splinters from the chutes through which the gravels were delivered at the experimental plant, it was necessary to wash these materials with a stream of water from a hose before they were used. None of the mortar sand required this washing.

The results of mechanical analyses of these materials are given in the next table. The stones and walnut gravel were hand picked, and the balance of the materials were analyzed with regular sand sieves, substantially as described by Mr. Hazen (Report, Massachusetts State Board of Health, 1892, page 541).

Mechanical Analyses of Gravels.
Percentages by Weight Finer than Given Diameters.

Stones.		Walnut Gravel.	
Size in Millimeters.	Percentage Finer.	Size in Milimeters.	Percentage Finer.
35	90.5	25	88.0
32	84.0	24	81.2
31	78.1	22	67.2
30	73.2	21	55.2
29	55.5	20	48.7
27	44.5	19	32.2
25	35.2	18	29.2
24	24.6	17	10.1
22	16.0	16	7.8
21	10.6	14	4.2
19	9.2	11	2.4
16	5.2	9	1.5
13	4.1	..	....
11	3.4	..	....
Effective size*	20.0		17.0
Uniformity coefficient*	1.5		1.2

Mechanical Analyses—Concluded.

Finer than (Millimeters).	Percentages by Weight.		
	Pea Gravel.	Buckshot Gravel.	Mortar Sand.
10.80	63.6	99.1	98.6
5.80	19.5	53.1	91.4
3.90	12.8	24.0	70.9
2.18	10.7	10.6	54.0
0.96	9.5	8.5	20 6
0.45	4.7	3.5	8.1
0.35	0.0	0.0	4.2
0.28	....	....	0.9
0.20	....	....	0.2
0.13	....	....	0 0
Effective size	1.47	1.83	0.52
Uniformity coefficient	6.5	3.6	5.4

*Throughout this entire report, unless otherwise specifically stated, "Effective size" means that 10 per cent by weight of the sand is finer than the given size in millimeters, and "Uniformity coefficient" is the ratio of $\frac{A}{B}$ when 60 per cent of the material is finer than A and 10 per cent finer than B.

Special Studies of Gravels.

The following special studies of the gravels used for underdrains were made:

Relative Lengths of Axes.—Current methods of mechanical analyses of filtering materials require the assumption that the middle diameter of a grain or stone is equal to the diameter of a sphere of equal volume. To ascertain the correctness of this assumption under local conditions, measurements were made of the axes of forty representative gravel stones, with the following results:

Material.	Relative Lengths of Axes.		
	Long.	Middle.	Short.
Stones	2.10	1.48	1.00
Walnut gravel	2.00	1.55	1.00
Pea gravel	2.20	1.64	1.00
Buckshot gravel	2.30	1.60	1.00
Average	2.15	1.56	1.00

In the case of these representative gravels the diameter of a sphere of equal volume would be 1.50. This indicates an error (in the assumption that the middle diameter equals the diameter of a sphere of equal volume) of 4 per cent on an average, while the error of individual results is far greater in some cases. Considering the average results, it does not seem probable that the error due to assumption or the methods of analyses is in excess of that of sampling.

Voids in the Gravel Layers—The percentage of voids in the several lots of gravel used as underdrains and supporting materials were determined by measurement of the amount of

water which could be added to a given volume of the material without increasing the space occupied. The following results were obtained:

Material.	Percentage of Voids.
Stones	36.1
Walnut gravel	35.1
Pea gravel	33.0
Buckshot gravel	31.0
Mortar sand	32.8

By compacting the gravel the percentage of voids could be reduced from 2.5 to 4.0 per cent. In the case of the mortar sand the reduction was from 1 to 3 per cent.

Sand Layers.

This section is devoted to a description of the sands used in the experimental English filters and of the manner of construction of the sand layers. In the next section there are presented the results of special studies of the sands readily available in the Ohio River at Cincinnati.

As has been stated, one of the fundamental objects of these investigations, as originally outlined, was the determination of the most efficient size of sand grain to employ in English filters receiving Ohio River water after two to three days of plain subsidence.

Primarily it was decided that economy demanded that river sands should be used in preference to bank sands. It was next decided to obtain, if possible, three grades substantially as follows:

1. As coarse a sand as could be readily obtained, but of an effective size of not over 0.40 millimeter.

2. A fine sand of about 0.20 millimeter effective size.

3. An intermediate grade.

These lots of sand were all pumped from the Ohio River on

December 27 and 30, 1897, and January 5, 1898; but, owing to partial loss in storage during the January rise, it was necessary to secure some more coarse sand. A new lot of coarse sand which had been collected from the exposed Dayton bar in the preceding fall was taken for the coarse grade.

The three lots representing well the available material in the river gave a very satisfactory range, and may be referred to comparatively as follows:

1. A fine sand such as is in use successfully on the continent of Europe, notably in Holland.

2. A medium sand of about the size which was used in the construction of the Lawrence City filter.

3. A coarse sand which represents closely the average of the best English and German practice.

All of the sands used in the construction of the English filters was obtained from the Ohio River, the first lot (for the original filters) from the Dayton sand bar and the second (for the later filters) from the Coney Island bar.

Some observations on these bars are presented just beyond in connection with the general study of the filtering materials obtainable from the Ohio River at Cincinnati.

A second problem which was presented in connection with these investigations was the most advisable thickness of the sand layer. General practice seemed to sanction 3 feet as the most suitable thickness, but there were some indications that a deeper layer might be both more efficient and possibly more economical. It was also considered advisable to determine, if possible, how far the thickness of the layer could be reduced by scraping without endangering its efficiency. Three thicknesses of layer—1 foot, 3 feet, and 5 feet—were therefore used in different filters; and in the construction of new filters layers 2.5 feet thick were used.

A detailed description of the construction of the sand layer and the results of special examinations of the sand are next presented in their logical order.

Construction of Sand Layers.

The sand for the layers of the original English filters, Nos. 1 to 15 inclusive, was all dumped into the filters from a runway laid over the top of the filter tanks. In so far as possible, the sand was distributed in the tank in dumping, but the larger portion of it was shoveled into place. It was found that the fall of the sand, which at the maximum was 6 feet in the shallow filters, 8 feet in the medium filters, and 10 feet in the deep filters, was sufficiently great to cause a compacting of the sand where it fell. This caused variations in the compactness of the sand layer, and resulted in unequal settling of the layer.

It was therefore necessary to relevel the surface of the sand layers at the first time of scraping, differences in level amounting to as much as 2 inches having developed. No further trouble was experienced in this connection.

In order to avoid compacting, two different methods of construction of the layers were subsequently employed. For filters Nos. 16 and 17, platforms were constructed at the side of and about 3 feet below the tops of the tanks. The sand was dumped on to these platforms, and was then shoveled into the tanks, each shovelful being spread as thrown. In this manner the entire layer was constructed, only the upper two or three inches requiring releveling in the tanks. No difficulties were experienced due to unequal settling of these layers, but the method seemed to be quite expensive.

For filters Nos. 18 and 19 the sand was delivered in gunny sacks, about 12 sacks to the cubic yard. These sacks were lowered into the tanks and opened in place, building the layer

continuously in advance. Very satisfactory results were obtained in this manner at a low cost.

Composition of Filtering Sands.

In all, 19 experimental filters of the English type were constructed and operated during these investigations. For this purpose four different lots of sand were used, as follows:

1. Fine sand, pumped from the Dayton sand bar on February 21, 1898. This sand was used in filters Nos. 1, 4, 7, 10, 13, 16, and 17.

2. Medium sand, which was a mixture of two lots of sand, pumped from the Dayton bar on December 27 and 30, 1897, the mixture being necessitated by the loss of a considerable portion of each lot during the high water of January, 1898. The sand layers of filters Nos. 2, 5, 8, 11, and 14 were constructed of this sand.

3. Coarse sand which was wheeled from the Dayton bar during low water of the fall of 1897, and which was used in constructing filters Nos. 3, 6, 9, 12, and 15.

4. Fine sand obtained from the Coney Island bar by pumping on August 22, 1898, and which was used for filters Nos. 18 and 19.

Size of Sand.—During the construction of these filters samples of the sand were collected for each foot of thickness of the layer. The results of mechanical analyses of these samples are presented in the following table. It is to be noted that in the case of filters Nos. 16 to 19, inclusive, the separate samples were mixed and the analyses were made of the mixture.

Mechanical Analyses of Filtering Materials.

Number of Filter.	Approximate Distance of Sample from Bottom of Sand Layer.	Uniformity Coefficient.	Effective Size.	Percentage by Weight of Material finer than (Millimeters).						
				2.18	0.96	0.45	0.35	0.28	0.20	0.13
1	0.5	1.6	0.21	99.19	97.90	90.15	68.55	35.67	7.72	0.72
	1.0	1.6	0.21	99.70	98.52	89.98	67.43	33.50	7.77	0.58
4	1 0	1.6	0.20	99.61	98.59	90.90	69.37	34.97	8.82	0.82
	2.0	1.6	0.20	99.73	98.53	90.98	69.49	35.61	9.50	0.78
	3.0	1.6	0.20	99.56	98.48	91.38	70.55	37.67	9.97	0.87
7	1.0	1.7	0.20	99.16	98.04	90.64	64.84	35.94	9.64	0.79
	2.0	1.6	0.20	99.65	98.48	90.54	67.50	34.76	8.97	0.80
	3.0	1.6	0.20	99.42	98.42	91.07	69.25	35.04	8.57	0.92
10	1.0	1.6	0.21	99.50	98.38	90.32	67.48	33.08	7.15	0.61
	2.0	1.6	0.21	99.60	98.60	89.37	65.03	30.79	6.92	0.62
	3.0	1.6	0.20	99.36	98.12	90.67	71.12	34.92	9.29	0.74
13	1.0	1.3	0.21	99.00	98.00	83.29	84.14	69.24	4.91	0.41
	2.0	1.3	0.21	98.83	97.48	91.68	81.47	65.72	4.69	0.51
	3.0	1.3	0.21	99.72	98.73	93.41	82.63	66.45	5.47	0.36
	4.0	1.3	0 21	99.58	98.69	93.99	81.40	63.08	5.78	0.41
	5.0	1.4	0.21	97.52	96.18	89 68	76.82	54.52	6.16	0.50
2	0.5	1.6	0.28	99.11	96 31	64.54	25.37	10.67	3.64	0.46
	1.0	1 5	0 28	99.76	97.56	69.36	26.56	10.78	2.92	0 38
5	1.0	1.6	0.28	98.76	95.80	62.79	24.18	10.23	3.05	0 39
	2.0	1.5	0.28	99.23	97.06	67.24	26.22	10.91	3.31	0 37
	3.0	1.6	0 28	98.69	96.09	61.89	24.46	10.47	3.02	0 42
8	1.0	1.5	0.28	99.19	97.25	68.65	26.05	10.94	3.25	0 44
	2.0	1.6	0.27	99.77	98.39	73.81	26.92	11.52	3.55	0 43
	3.0	1.5	0.28	99.62	98.15	72.41	26.45	10.93	3.38	0 41
11	1.0	1.5	0.28	99.28	97.15	68.64	26.15	10.76	2.90	0 40
	2.0	1.5	0.28	99.48	97.28	67.74	24.82	10.41	3.07	0.37
	3.0	1.5	0.28	98.98	96.84	68.34	26.01	10 85	3.52	0.39

Mechanical Analyses—Concluded.

Number of Filter.	Approximate Distance of Sample from Bottom of Sand Layer.	Uniformity Coefficient.	Effective Size.	Percentage by Weight of Material finer than (Millimeters).						
				2.18	0.96	0.45	0.35	0.28	0.20	0.13
14	1.0	1.5	0.27	99.85	98.53	74.83	27.70	11.83	3.86	0.48
	2.0	1.6	0.28	99.02	96.14	61.57	22.41	8.81	2.63	0.31
	3.0	1.6	0.27	99.24	96.46	62.21	23.77	10.75	3.36	0.42
	4.0	1.6	0.27	99.52	97.03	66.64	26.41	11.15	3.48	0.36
	5.0	1.5	0.27	99.80	98.79	79.05	29.73	12.32	3.58	0.36
3	0.5	1.9	0.33	96.27	93.68	47.82	11.26	6.20	2.51	0.60
	1.0	2.0	0.34	95.15	92.60	46.78	10.34	5.79	2.12	0.52
6	1.0	1.9	0.35	94.28	91.84	44.95	9.98	5.83	2.13	0.53
	2.0	1.9	0.34	97.68	95.08	46.23	10.99	6.39	2.37	0.56
	3.0	1.8	0.34	98.35	95.91	47.33	10.75	6.07	2.39	0.58
9	1.0	1.9	0 34	96.48	93.73	45.69	10.90	5.95	2.35	0.50
	2.0	1.8	0.35	95.20	92.70	44.50	9.93	5.88	1.98	0.53
	3.0	1.9	0.34	95.50	93.09	45.59	10.54	5.87	2.17	0.50
12	1.0	1.9	0.34	94.20	91.28	44.18	10.28	5.31	2.37	0.53
	2.0	1.8	0.35	97.54	94.64	45.59	9.76	5.19	2.03	0.47
	3.0	1.9	0.35	98.85	91.10	44.49	9.81	5.56	2.17	0.60
15	1.0	1.9	0.33	97.25	94.99	47.72	11.72	6.87	2.66	0.72
	2.0	1.9	0.36	89.63	86.95	43.11	9.52	5.12	1.99	0.54
	3.0	1.9	0.34	97.08	94.01	46.88	11.09	5.86	2.59	0.64
	4.0	1.9	0.34	96.78	94.29	47.09	10.39	5.31	2.20	0.45
	5.0	1 9	0.35	94.77	91.89	45.03	10.15	5.40	2.24	0.50
16–17	Average	1.6	0.21	99.42	98.31	90.58	69.25	36.78	7.82	0.68
18	"	1.5	0.22	100.00	99.94	97.09	72.39	33.14	8.54	0.24
19	"	1.5	0.22	100.00	99.89	69.39	69.39	30.69	8.01	0.25

Special Examinations of Filtering Sands.

Relative Lengths of Axes.—Considerable attention was devoted to this question as it is fundamental in connection with the current methods of measuring the size of sand grains as

stated in reference to the gravels. About 200 representative sand grains obtained from the Dayton bar were measured. All grains above and including those which remained upon a No. 20 sieve (0.96—millimeter openings) were measured with a micrometer caliper, and the finer grains were measured under the microscope. The results of these examinations are given in the following table:

Relative Lengths of Axes of Filtering Sands.

*Size of Sieve.	Relative Lengths of Axes.		
	Long.	Middle.	Short.
FINE SAND.			
3.90	2.80	1.89	1.00
2.18	2.16	1.55	1.00
0.96	2.50	1.70	1 00
0.45	1.80	1.40	1.00
0.35	2.10	1.60	1.00
0.28	2.30	1 70	1.00
0.20	2.00	1.50	1.00
0.13	1.94	1.48	1.00
MEDIUM SAND.			
5.80	1.92	1.40	1.00
3.90	2 50	2.20	1.00
2.18	2.80	2.17	1.00
0.96	1.60	1.10	1.00
0.45	2.00	1.46	1.00
0.35	2.00	1.71	1.00
0.28	2.00	1.33	1.00
0.20	1.92	1.64	1.00
0 13	1.83	1.50	1.00
COARSE SAND.			
5.80	2.10	1.50	1.00
3.90	2.40	1.70	1.00
2.18	2.30	1.60	1.00
0.96	2.50	1.60	1.00
0.45	2.00	1.60	1.00
0.35	1.90	1.50	1.00
0.28	2.20	1.60	1.00
0.20	1.90	1.60	1.00
0.13	2.00	1.50	1.00

*Diameter of openings in millimeters.

Separating the above results according to the method of measurement (calipers or microscope), the following averages are obtained:

GRAINS.	Relative Lengths of Axes. Long.	Middle.	Short.
Left on 0.96 m. m. sieve	2.32	1.67	1.00
Passed through 0.96 m. m. sieve	1.98	1.58	1.00

Comparing these figures with a sphere of equal volume, it is found that the error in assuming the middle diameter of the sand grains equal to the diameter of the sphere is 6 and 5 per cent, respectively, in the two cases. As this error is practically a constant for sands from the same general source, and considering the difficulty of sampling sands as they occur in river beds and sand banks, it is evident that the stated assumption does not lead to serious error with these materials. With filtering sands the effective size would not ordinarily be affected more than 0.01 millimeter.

Voids in the Filtering Sands.—The percentage of voids in the filtering sands obtained from the Dayton bar was determined in the same manner as in the case of the gravels, with the following results:

MATERIAL.	PERCENTAGE OF VOIDS.
Fine sand	44.2
Medium sand	43.1
Coarse sand	41.7

By compacting the sands by ramming, the voids could be reduced from 1 to 3 per cent.

Organic Matter on the Filtering Sands.

The organic matter on the grains of the filtering sands, expressed as nitrogen in the form of albuminoid ammonia, was found on an average to be as follows:

MATERIAL.	NITROGEN AS ALBUMINOID AMMONIA.
Fine sand (Dayton)	...Parts per million, 19.0
Medium sand (Dayton)	" " 23.0
Coarse sand (Dayton)	" " 27.0
Coney Island sand	" " 26.0

Bacteria on the Filtering Sands.

Bacterial examinations of the various lots of filtering sands were made on representative samples. Special studies of the species of bacteria most prevalent were made; but, other than the fact that the species corresponded with leading ones in the river water, no especial points of value were learned. The numbers of bacteria found averaged as follows:

MATERIAL.	BACTERIA PER GRAM OF SAND.
Fine sand (Dayton)	180,000
Medium sand (Dayton)	290,000
Coarse sand (Dayton)	440,000
Coney Island sand	280,000

Clay on the Filtering Sands.

Known weights of the several lots of sand after drying were shaken up with distilled water until a practically clear wash water was obtained. Results of the determinations of the amount of material removed from the sand in this manner, expressed in parts per million of dry sand, are given in following table:

MATERIAL.		CLAY.
Fine sand (Dayton)	Parts per million,	2,900
Medium sand (Dayton)	" "	2,100
Coarse sand (Dayton)	" "	2,800
Coney Island sand	" "	900

Chemical Composition of Filtering Sands.

All of the sands used were composed chiefly of silica in the form of quartz. From 96.5 to 97.0 per cent was found to be insoluble in strong hydrochloric acid after treatment for 24 hours. These figures represent the amount of pure quartz, stable silicates, and coal. After igniting the insoluble residue, the loss, probably corresponding approximately to the amount of coal, was found to be as follows:

MATERIAL.		PERCENTAGE.
Fine sand (Dayton)	Loss of residue upon ignition—coal,	2.14
Medium sand (Dayton)	" " "	2.24
Coarse sand (Dayton)	" " "	1.29
Coney Island sand	" " "	0.27

The amount of lime and magnesia in the whole sample and in the finest 10 per cent of the filtering sands was found to be as follows:

Material.		Parts per Million.	
		Lime ($CaCO_3$).	Magnesia ($MgCO_3$).
Fine sand (Dayton)	Total	3,400	1,700
	Finest 10 per cent	3,800	3,800
Medium sand (Dayton)	Total	300	6,300
	Finest 10 per cent	7,700	4,800
Coarse sand (Dayton)	Total	4,700	4,000
	Finest 10 per cent	4,100	3,100
Coney Island sand	Total	1,800	2,400
	Finest 10 per cent	1,800	2,400

The iron and alumina in the finest 10 per cent and the iron in the total sample were determined with the following results:

Material.		Parts per Million.	
		Iron (Fe_2O_3).	Alumina (Al_2O_3).
Fine sand (Dayton)	Total	17,700	.....
	Finest 10 per cent	19,700	1,800
Medium sand (Dayton)	Total	16,300	.....
	Finest 10 per cent	16,800	2,800
Coarse sand (Dayton)	Total	13,400	.....
	Finest 10 per cent	14,100	1,600
Coney Island sand	Total	13,100	4,600
	Finest 10 per cent	14,000	5,800

Approximate Mineralogical Composition of Filtering Sands.

All of the sands used in these experiments, and which were collected from sand bars in the Ohio River near Cincinnati, were composed almost wholly of débris from the glacial drift deposits. They are, as presented above, almost entirely silicious, with small amounts of coal and limestone. Most of the material, especially the larger grains, is very stable in composition.

In the following tables are given approximate mineralogical analyses of the sands collected from the Dayton bar, as

they were separated on the different screens. With regard to the sand from the Coney Island bar, there is no reason for believing that it is appreciably different from the fine sand from the Dayton bar, except in the amount of coal and clay, as indicated by figures already presented.

Approximate Mineralogical Analysis of Sand.

FINE SAND.

Size of Sieve in Millimeters.	Percentage Separated.	Estimated Percentage of Materials Present.				
		Coal.	Limestone.	Sandstone	Quartz.	Hard Silicates.
3 94	0.16	10	20	50	....	20
2.18	0.32	5	....	25	5	65
0.96	1.28	5	....	20	25	50
0.45	17.81	5	....	...	75	20
0.35	50.55	5	....	....	80	15
0.28	10.79	5	....	....	90	5
0.20	18.05	2	....	....	95	3
0.13	5.13	2	....	....	95	3
Residue	0 75	Quartz,	hard	silicates,	and coal.	

MEDIUM SAND.

3.94	0.08	5	....	60	....	35
2.18	0.55	5	....	10	10	75
0.96	2.26	5	5	10	15	65
0.45	65.83	5	....	....	75	20
0.35	19.85	3	....	....	85	12
0.28	4.17	2	....	....	90	8
0.20	4.56	2	....	....	95	3
0.13	2.42	2	....	....	95	3
Residue	0.26	Quartz,	hard	silicates,	and coal.	

COARSE SAND.

5.77	1.64	5	10	20	....	65
3.94	1.06	5	10	10	5	70
2.18	1.29	....	10	10	10	70
0.96	2.19	3	10	....	27	60
0.45	53.80	5	....	....	75	20
0.35	26.58	3	....	....	85	12
0.28	5.76	3	...	....	90	7
0.20	4.75	2	....	....	95	3
0.13	2 40	2	....	....	95	3
Residue	0.53	Quartz,	hard	silicates,	and coal.	

FILTERING MATERIALS OBTAINABLE FROM THE OHIO RIVER NEAR CINCINNATI.

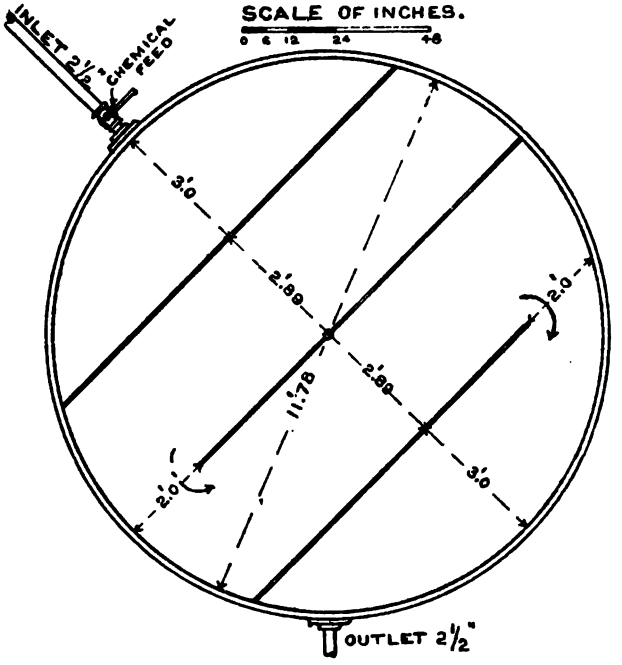
There are two main sand bars within the vicinity of the new works at California. The larger of these occurs at a bend of the river opposite Dayton, Ky., from 2.5 to 5 miles below the new intake at California. It starts from about half a mile below the bend and runs for about two miles up the river. This bar ranges from 100 to 1,000 feet wide, and for the majority of its length it is over 500 feet in width.

Perhaps the most characteristic feature of this bar is the widely varying character of the material of which it is composed. Close to the shore the sand is very fine, and at the edge of the channel considerable gravel is present. Between these two grades the changes are very rapid in places, differences of 50 feet in the position of the pump making very marked differences in the character of the material obtained. Ordinarily the sand companies pump their sand at the last turn of the bend, about opposite Jackson Street, Dayton. This point is below the limits of the "coal harbor," and a considerable amount of coal is found in the sand. To some extent the bar at this point appears to be shifting; and, with the variations in depositions, it is necessary to pump at different places during different stages in order to obtain the same grade of sand. While there are considerable amounts of gravel found towards the edge of the channel, they are as a rule mixed with so much sand as to be uneconomical to handle in securing gravel.

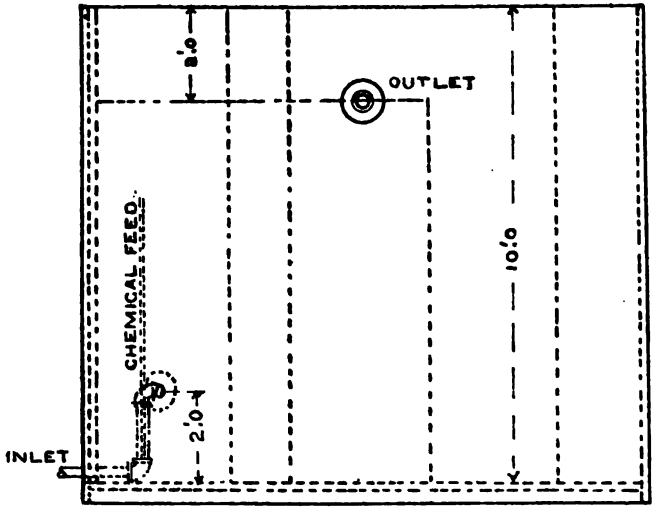
Beginning about 0.5 mile below Coney Island, or about 1.25 miles above the new intake at California, and running to opposite the upper end of the island, is a series of bars, which, practically speaking, join together, and form one bar about 3,000 feet long and from 100 to 500 feet wide. These bars

PLATE VI.

TANK-E.



PLAN.



ELEVATION.

divide the Kentucky and the Ohio channels, and sand of a remarkable uniformity can be obtained here. Apparently the sand is somewhat coarser near the edges of the bars, but the major portion of the bars is composed of material of a very uniform character. In the examination of these bars, sand was pumped from different places covering an area of about 250 by 1,000 feet, and not more than 0.02 millimeter difference was found in the effective size of the sand pumped. At several different points the sand was pumped from different depths below the surface of the bar, but no appreciable difference in the character of the sand could be found even when the end of the pipe was lowered nearly 15 feet below the surface of the bar. As this bar is considerably above the harbor line, there is but little coal present in the sand.

The only gravel bank of importance is said to be on the Ohio shore, running for about 0.5 mile up from Coney Island. Here apparently gravels and boulders of a considerable size can be obtained comparatively free from sand.

DESCRIPTION OF SUPPLEMENTARY SUBSIDING BASIN E.

For the purpose of obtaining at times additional clarification of the subsided water, aided by the application of a coagulant, use was made of the wooden tank originally used for filter No. 15. The sand and gravel were removed from the tank and new piping connections were made. Baffle walls were built in order to prevent the direct passage of the water from the inlet to the outlet. The arrangement of these walls and of the piping system is shown on Plate VI.

Capacity.—This basin, which in its new form was known as basin E, was 11.78 feet in diameter and 10 feet deep, inside measurements. The normal depth of water was about 8.9 feet, giving a capacity of 970 cubic feet. With both filters

Nos. 16 and 17 in operation at their original rates, the theoretical period of displacement was 10 hours and 33 minutes. Actual observation of the rate of flow, by means of the chemical applied, indicated that the average period of effective subsidence corresponded approximately to the capacity of the tank, but that some water passed through in 50 per cent of the average time.

Piping.—For the supply connection was made with the 3-inch pipe which originally supplied the subsided water to the filters Nos. 6 and 15, and the original inlet connection was plugged. This connection was made of 2.5-inch wrought iron pipe, and a check valve and stop valve were placed on the line. Just before this pipe connected with the tank, there was connected a 0.5-inch lead pipe through which a solution of sulphate of alumina could be applied. The distance from the point of application of the chemical to the tank was 2.0 feet and included one right angle bend. The connection of the inlet to the subsiding tank was by a flange joint flush on the outside of the tank. From the bottom of the tank to the center of the inlet pipe was 2.0 feet.

The 2.5-inch outlet pipe was connected by a flange joint to the side of the tank 2.0 feet below the top and 0.9 foot below the normal water line. The angle between the inlet and outlet pipes was 130°.

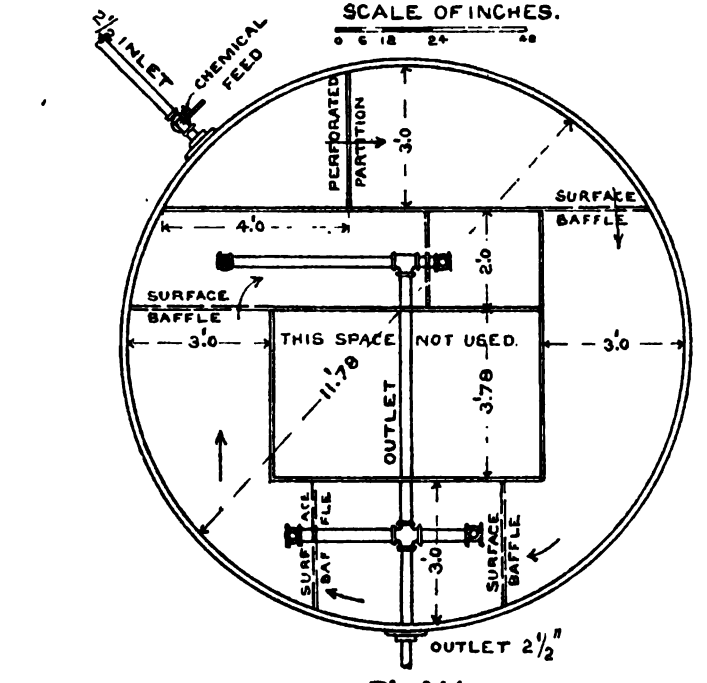
For the purpose of draining the tank the old outlet and side filling connections were broken, and these 1.5-inch pipes were used as drain pipes. Cleaning was done with a stream of water from a hose and with a broom after the tank was drained.

Modifications of Basin E.

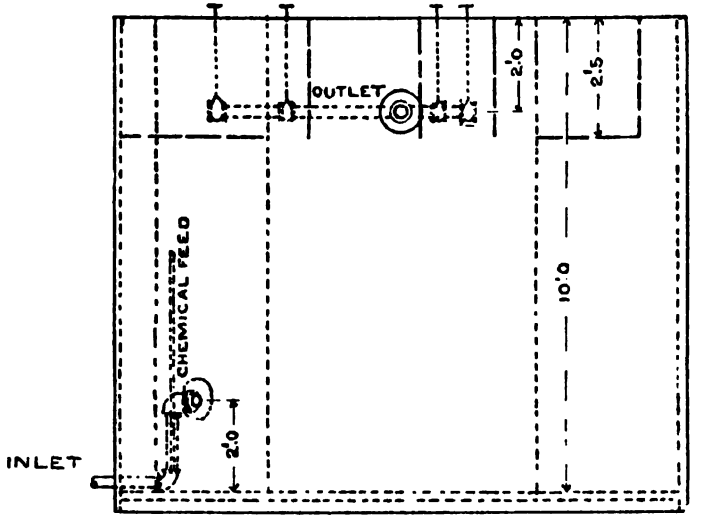
On September 26 the arrangement of baffle walls in this basin was modified in order to allow use of the tank for subsidence in connection with filter No. 16 alone, it having been

PLATE VII.

MODIFICATIONS OF TANK-E.



PLAN.



ELEVATION.

decided to shut down filter No. 17. For the purpose of studying the effect of different periods of subsidence, the baffle walls were constructed so that 5 and 7.5 hours of effective subsidence could be obtained at rates of both four and five million gallons per acre per day for filter No. 16. The arrangement of the baffle walls and outlet pipe will be best understood from Plate No. VII. It will be seen that there was provided a continuous channel for the water, and that by the use of the proper outlet valve either period of subsidence at either rate could be obtained. Surface baffles extending 12 inches below the surface of the water were provided to prevent the water from sliding over the surface, and the current at the inlet was broken by a perforated partition. The outlet pipes were all on the same level, 2 feet below the top of the basin.

On November 29 the baffle walls in this basin were again modified in order to obtain as nearly as practicable complete displacement in the tank for use in connection with filter No. 16. The location of baffle walls as thus modified was practically the same as in basins F, G, and H.

DEVICES FOR PREPARING THE CHEMICAL SOLUTIONS AND FOR APPLYING THE COAGULANT AT BASIN E.

The general arrangement of these devices, as originally constructed, is shown on Plate No. VIII in full lines.

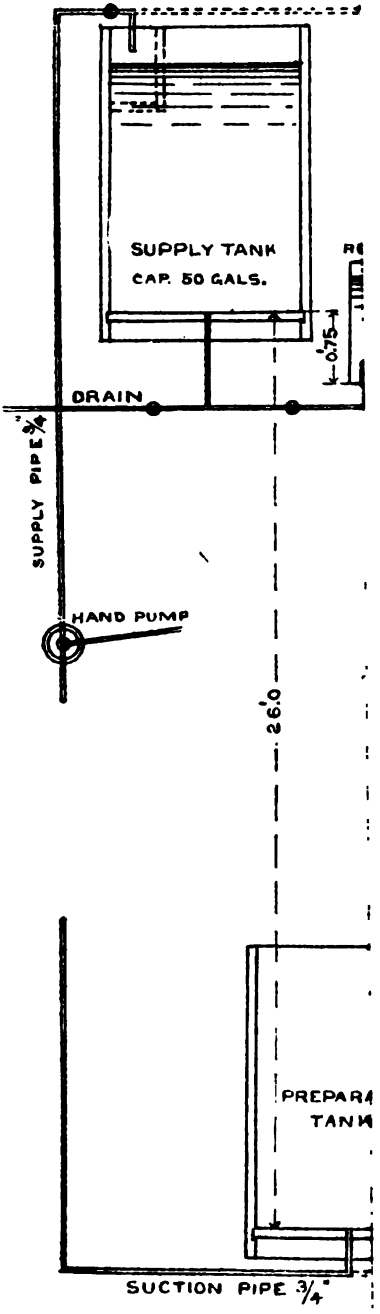
Chemical.—Sulphate of alumina was used as a coagulant and was prepared in weak solutions.

Chemical Tanks.—Two wooden tanks, each 2 feet in diameter and 3 feet deep, inside measurements, were used for the preparation of solutions. The tanks were regularly filled to a depth of 2.75 feet, at which depth they held 400 pounds of water. During the first operations with the modified English

system the solutions were made in one of these tanks located in the meter room, by attaching a hose to the outlet of one of the filters and letting filtered water discharge into the tank over the chemical which was held in a box at the side of the tank. These solutions normally had a strength of 1 per cent of the applied chemical. By this arrangement the chemical was all dissolved when the tank was full. The other tank was used as a supply tank, and the solution was pumped by a hand pump through a 0.75-inch lead pipe to the supply tank as often as was needed.

The supply tank was located in an extension of the original gage room at the south end of the filter tank platform. From the platform to the bottom of the tank was 16.25 feet, or the bottom of the tank was 6.25 feet above the normal level of the water in basin E.

Regulating Tank.—A 0.5-inch brass pipe connected the supply tank with the regulating tank. This was a copper tank 1.00 foot in diameter and 1.25 feet deep. The bottom of this tank was 14.25 feet above the platform, or 5.50 feet above the level of the water in basin E. By means of a piston valve on the end of the inlet pipe, operated by a float, the level of the solution was maintained practically constant (variation 0.25 inch) and independent of the level in the supply tank. From the regulating tank the solution passed through a 0.5-inch pet cock and discharged freely into a funnel on the end of the 0.5-inch lead pipe which connected to the inlet of subsiding basin E. The rate of flow was regulated by the pet cock using half-hourly observations of the quantity by means of a graduated glass cylinder. As the head in the regulating tank was practically constant, very little variation was found in the rate of flow, the maximum being about 5 per cent, which seemed to come at times on account of coatings on the brass tubes.


SUPPLY TANK
CAP. 50 GALS.
0.75
DRAIN
SUPPLY PIPE 3/4"
HAND PUMP
26'0
PREPARA
TANK
SUCTION PIPE 3/4"

This action was cumulative, and it was necessary to flush the pet cock about once a week with a free flow of the solution for one or two minutes.

Re-arrangement of Chemical Devices.—With the introduction of the American system (filter No. 20) it was decided to re-arrange the chemical devices somewhat. Accordingly, on September 10, 1898, the second wooden tank which had been used for preparing the solutions was raised to the same height as the supply tank. A 0.5-inch connection was then made from this tank to the regulating tank, and suitable valves were provided so that either of the wooden tanks could be used as a supply for the regulating tank. Filtered water was supplied by a hydraulic pump, which was also used for supplying the tank where the water used in washing filter No. 20 was stored. The general arrangement of the modified devices is shown on Plate No. IX by the full and dotted lines, which with the descriptions will be readily understood.

After this time the two tanks were used alternately, solutions being made in one while the other was being used as a supply tank. The solutions were prepared by filling the tank slowly, the water discharging into a box on the side of the tank where the chemical was placed. No difficulty was experienced in dissolving the chemical, using about 45 minutes to fill the tank. Suitable glass gages were provided to observe the level of the solution in the tanks. Up to October 28, unless a change was made in the strength of the solution, the contents of the tank were drawn down to 2 inches from the bottom and 400 pounds of water were added to make the new solution. When a change in the strength of solutions was made, the tank was drained dry before the new solution was prepared, 400 pounds being used as before. Reference points were used to determine the depth to fill the tanks, these points having

been determined by weight calibration. Owing to variations in strength, which were sufficient to reduce in a measure the accuracy of the work, it was decided on October 28 to stir regularly the solutions during use. This resulted in the introduction of the accumulated insoluble residue into the regulating tanks with a consequent interference with the regulating valves. It was therefore necessary to remove this residue, and after this date the tanks were regularly cleaned before making up a new solution.

DESCRIPTION OF FILTERS NOS. 16 AND 17.

In connection with the modified English system two sand filters were made, which were duplicates in the method of construction. For these filters the sand layer was removed from filters Nos. 6 and 12 down to the mortar sand which formed the upper layer of the underdrains. There was then placed in each filter 30 inches of fine sand which had been thoroughly washed. Some of this sand had been used in other filters from which it was removed in scraping. The balance was sand remaining from the original supply. All of this sand was passed through six hoppers of the ejector washing machine, and practically all of the loose material on it was removed.

Piping System.—The only change in the piping system was the introduction of a new 1.5-inch inlet from basin E to each filter. These connections were made by a flange joint at the same elevation as the old inlets to filters Nos. 6 and 12, 4.7 feet below the top of the tank. With the 30-inch sand layer the center of the inlet was 6 inches above the top of the layer.

Filtering Materials.

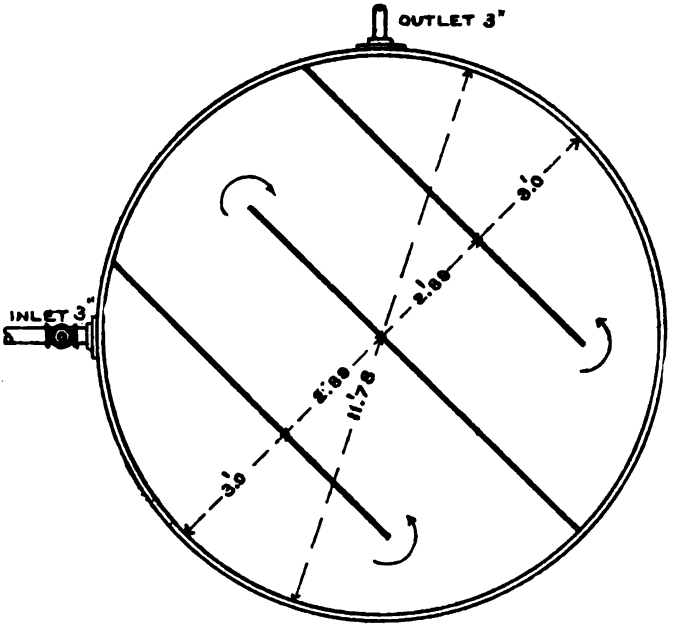
A full description of the filtering materials used in the English filters has been presented in the preceding sections,

PLATE IX

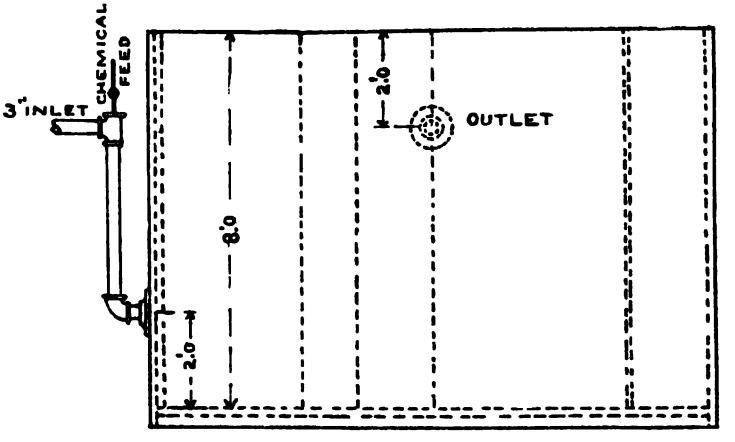
TANKS F-G-H.

SCALE OF INCHES.

0 6 12 24 48



PLAN.



ELEVATION.

and there will be given here only the essential details in connection with these two filters.

Construction of Sand Layer. — In constructing the sand layer of these two filters, the sand was spread from a shovel from the top of the tank. Constant watch was maintained to keep the surface of the layer as nearly level as practicable as the sand was put in place. That this procedure of spreading from a height of from 5 to 8 feet was quite satisfactory was shown by the fact that the settlement of the sand layers in these filters was very uniform, and amounting to about 10 per cent of the thickness of the layer.

Character of Sand.—The sand was somewhat cleaner than when it was used originally to charge the English filters, as will be seen by the following results:

	Bacteria per Gram.	Parts per Million.	
		Clay.	Nitrogen as Albuminoid Ammonia.
Fine sand as originally used.....	183,000	2,900	27.0
Fine sand after washing	4,900	1,100	23.0

Size of Sand. — Mechanical analyses of the sand used for these two filters were presented in the preceding sections, but as a matter of convenience they will be repeated here:

Number of Filter.	Sample.	Uniformity Coefficient.	Effective Size.	Percentage by Weight finer than (Millimeters).						
				2.18	0.96	0.45	0.35	0.28	0.20	0.13
16–17	Average	1.6	0.21	99.42	98.31	90.58	69.25	36.78	7.82	0.68

DESCRIPTION OF FILTERS NOS. 18 AND 19.

In order to study the effect of washing the sand before charging the filters, the sand layer was removed from filters Nos. 12 and 13, and these tanks were recharged with 30 inches each of new washed and unwashed sand, respectively. They were then numbered 18 and 19, the former containing the unwashed and the latter the washed sand. No changes were made in the filters other than the introduction of the new sand layer. In order to prevent unequal compacting the sand was raised into the filters in sacks and spread in place.

Filtering Materials.

In the construction of these filters sand pumped from the bar in the Ohio River opposite Coney Island was used. A description of this bar and a discussion of the character and amount of sand obtainable from it has been already presented.

Experiment indicated that but little material could be removed from this sand by the sand washing machine. Some slight cleaning (mainly in removal of bacteria) took place in the first two hoppers of the ejector washing machine, and the sand for filter No. 19 was accordingly passed through these two hoppers. Mechanical analyses of these sands and examinations for clay, organic matter, and bacteria have already been presented, but as a matter of convenience they are repeated here.

Examination of Sand used in Filters Nos. 18 *and* 19.

Sand.	Filter No. 18. Unwashed.	Filter No. 19. Washed.
Per cent by weight finer than 0.96 millimeters.	99.94	99.89
" " " 0.45 "	97.09	95.59
" " " 0.35 "	72.39	69.39
" " " 0.28 "	33.14	30.69
" " " 0.20 "	3.54	3.01
" " " 0.13 "	0.24	0.25
Effective size	0.22	0.22
Uniformity coefficient	1.50	1.50
Clay, parts per million	900.00	900.00
Nitrogen as albuminoid ammonia, parts per million	26.00	26.00
Bacteria per gram	280,000	27,000

DESCRIPTION OF COAGULATING BASINS F, G, AND H.

In connection with filter No. 20 (American system) three coagulating basins were prepared through which the water could be passed after receiving the application of sulphate of alumina. The use of these basins is discussed beyond.

Basin F.

This basin was originally used as filter No. 8. It was 11.78 feet in diameter and 8 feet deep, inside measurements. At the normal level of the water, 12 inches below the top of the basin, it had a capacity of 763 cubic feet.

Observations of the displacement of the water in this basin indicated that at the normal rate of 3.25 cubic feet per minute the period was about 2.3 hours on an average, but that some water passed through in about 50 per cent of the average period.

Piping.—The inlet to this basin was a 3.5-inch wrought iron pipe connected to the main subsided water supply pipe from the regulating tank. This pipe connected with the

basin on the north side 2.0 feet above the bottom by means of a flange joint. There was provided in this pipe a check valve, a stop valve, a branch which served as an inlet to basin G when F was not in use, and, at a point 6.0 feet from the connection with the basin, a connection with the 0.5-inch lead pipe used as a chemical feed pipe. Between this connection and the basin there were 3.5 feet of 3.5-inch pipe and one elbow. Except in filling, the valve on the inlet pipe was left wide open.

The outlet was a 3-inch pipe connected by a flange joint at a point 90° from the inlet pipe and 2.0 feet below the top of the basin. This pipe was joined to the inlet to basin G, which branched from the inlet to basin F. From the connection of these two pipes, one pipe led to basin G, as described beyond.

Baffle Walls. — In order to obtain as nearly complete displacement in this basin as practicable, baffle walls were constructed, as shown on Plate IX. As will be seen, these walls were three in number, dividing the diameter of the tank into four approximately equal parts. All partitions extended to the top of the basin and were open at alternate ends for their full height, leaving a passage about 2 feet wide. Under these conditions an average period of subsidence of 3.5 hours, corresponding approximately to the capacity of the tank, was obtained, but some water came through in less than 2.0 hours.

Drains.—Use was made of the old outlet and side filling pipes (each 1.5-inch in diameter) as drain pipes. The outlet pipe was arranged to discharge into the sewer in the meter room, and the side filling pipe was arranged to drain into a ditch below the basin.

Basin G.

This basin, which was formerly used as filter No. 5, was practically a duplicate of basin F described above. The inlet connected at a point 2.0 feet above the bottom, and the outlet at a point 2.0 feet below the top, the two being separated by an angle of 90°. At a point 6.0 feet from the basin there was a connection of the 0.5-inch lead pipe used as a chemical feed pipe to the inlet pipe. Between this connection and the inlet opening in the basin there were 3.5 feet of 3-inch pipe and one elbow. The 3-inch outlet pipe connected with basin H. The supply for this basin could be taken either directly from the main subsided water supply pipe from the regulating tank or after passing through basin F, as desired. Baffle walls identical with those in basin F were provided. For draining use was made of the old outlet and side filling valves, as described for basin F.

The average displacement of this tank as indicated by the passage of colored solutions was about 3.5 hours, but as in the case of basin F, some water came through in less than 2.0 hours.

Basin H.

For this basin use was made of the tank originally used for filter No. 3. The basin was 11.78 feet in diameter and 6 feet deep. At the normal depth of water of 5.0 feet it held 545 cubic feet. Tests with chemical solutions indicated that some of the water passed through this basin in less than 1.5 hours, but that all of it did not come through for over 3.5 hours. On an average the displacement corresponded approximately to the capacity of the basin, or 2.5 hours' flow.

Piping.—The inlet pipe (the outlet from basin G) connected with this basin by a flange joint 1.5 feet above the bottom

of the basin. At a point 40 feet from the basin there was connected a 0.5-inch lead pipe through which the chemical solution was fed. Between this connection and the filter there were 2.5 feet of 3-inch pipe and one elbow.

The outlet pipe was connected at a point 90° from the inlet and 2.0 feet below the top of the basin. This pipe was 3 inches in diameter and connected directly with filter No. 20.

Baffle Walls.—Three baffle walls arranged identically as those in basins F and G were built, extending to the top of the tank. (See Plate IX.)

Modifications of Inlet.—On October 8 the inlet pipe was modified by an extension of the pipe into the basin, as shown on Plate X. At three points on this pipe and branches therefrom, all of which were 2 feet above the bottom of the basin, valves were provided to allow the water to be admitted to the basin at any one of three points. These points were so located that at the normal rate of flow and the theoretical displacement, 0.5, 1.0, and 2.5 hours would be occupied in the passage of the water to the outlet from the three inlet openings, respectively.

The average period of coagulation and subsidence available with these three inlets was approximately as follows:

Inlet No. 1	0.5 hour.
Inlet No. 2	1.0 hour.
Inlet No. 3	2.5 hours.

Devices for the Application of the Coagulant to Basins F, G, and H.

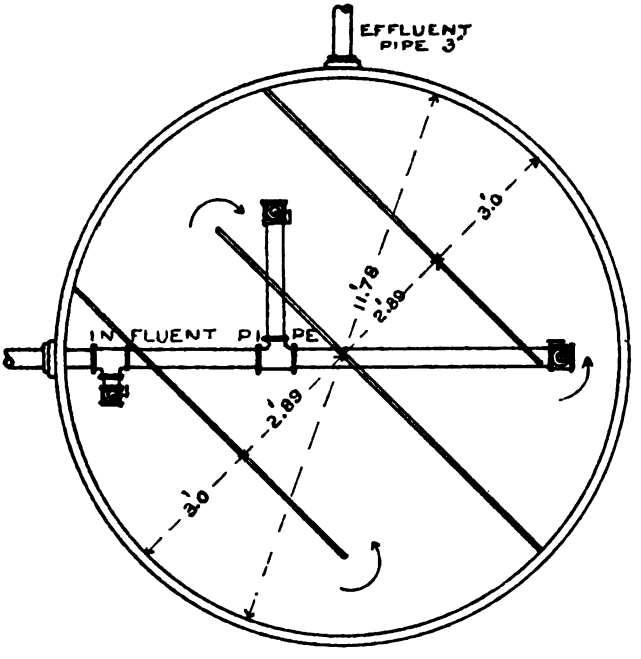
In the preparation of chemical solutions use was made of the devices for preparing the solution to apply to basin E, as above described. For the use of the American system the only change made, except as described in connection with the application to basin E, was the introduction of a new outlet from the regu-

PLATE X.

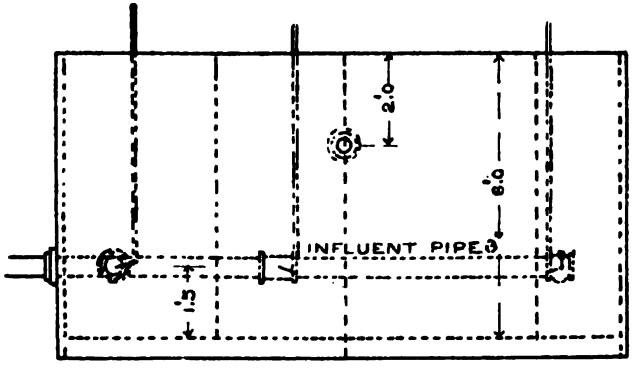
MODIFICATIONS OF INFLUENT PIPE, TANK-H.

SCALE OF INCHES.

0 6 12 24 48



PLAN.



ELEVATION

lating tank. From this tank the solution fed into a funnel on the end of a 0.5-inch lead pipe which was connected with the inlets to basins F, G, and H, as above described. Valves at these inlets allowed the application of the chemical at any one of the three points as desired. Regulation of the rate was made from half-hourly observations of the rate of flow by measurement in a graduated glass cylinder, and adjustment of the discharge valve at the regulating tank when necessary.

On November 11 a new 0.5-inch chemical feed pipe, with regulating valve and funnel the same as the others, was constructed so as to discharge chemical into the water as it passed from basin H into the inlet to filter No. 20.

Wash Water Supply for Filter No. 20.

Filtered water was used for washing filter No. 20. It was supplied from a storage tank located above the filter and enclosed in the same room. This was a wooden tank 11.78 feet in diameter and 6.0 feet deep. When filled to the overflow (6 inches below the top) it held 600 cubic feet of water. Water was supplied to this tank by a water motor pumping the water from the filtered water trough in the meter room. From the bottom of the tank a 2-inch pipe connected with the outlet from filter No. 20.

The maximum pressure available in this pipe was 14.75 feet and the minimum was 9.25 feet. Deducting from these figures the pressure in the filter during washing, the maximum and minimum acting head were 11.25 and 5.75 feet, respectively. Normally the acting head was from 10 to 11 feet.

Measurement of the wash water was obtained from gage readings of the level of the water in the tank before and after washing, the pump being stopped while the gages were being read.

DESCRIPTION OF FILTER NO. 20.

Filter No. 20 was a 4-foot gravity filter of the American type, constructed by and purchased from the O. H. Jewell Filter Company of Chicago, Ill. There were no marked departures in the design of this filter from the style of construction of this type of filters, except that the filter was separate from the basins in which coagulation took place. In general the filter may be said to have consisted of a steel tank which was occupied by a compartment for the collection of filtered water, a layer of sand, and an open compartment above the sand. There was also provided a device for agitating the sand layer during washing. These parts are taken up and described in order.

Steel Tank.

The tank which held the sand layer was composed of two parts, an inner and an outer tank. The arrangement of this tank is shown on Plate XI, where an outline plan and section of this filter are shown, respectively. The inner tank was 4 feet in diameter and 3.75 feet deep, inside measurements. Three inches above the bottom of the tank there was a horizontal partition which formed a support for the sand layer. Into this partition the strainer cups, fifty in number, were screwed, and the space between this false and the true bottom of the tank was used as a filtered water chamber. This chamber held approximately 3.14 cubic feet, or slightly less than one minute's normal flow from the filter.

The main portion of the inner tank was occupied by the sand layer, which was 32 inches thick, leaving 30 inches above the top of the opening of the strainer cups. The upper 10 inches of this tank were occupied by the water to be filtered.

At a point 2.0 feet above the bottom of the inner tank there

was connected an outer tank. This tank was 4.67 feet in diameter and 3.33 feet deep. Between it and the inner tank there was a space of 3.75 inches wide and 2.00 feet deep, which served as a circumferential trough to remove the wash water as it spilled over the edge of the inner tank in washing, and also to distribute the water applied to the filter during filtration. Above the inner tank the space 16 inches in depth was ordinarily filled to about 12 inches with the water to be filtered. The entire space above the sand layer was about 30 cubic feet in capacity.

Piping Connections.—The outlet and wash water supply pipes (2 inches in diameter) were joined just outside the filter and connected to the filter 1.5 inches above the bottom of the inner tank. At a point 3.33 feet below the top of the tank the 2-inch inlet pipe was connected to the outer tank. From the bottom of the outer tank a 3-inch pipe was connected to the sewer to carry off the water during washing. A 1.5-inch branch from the inlet pipe just outside the filter was connected with the sewer for the purpose of wasting the water when it was desired to change the water in the coagulating basins.

Strainer System.—Slotted brass cups, fifty in number, formed the strainer system of this filter. They were screwed into the false bottom, and were spaced at not more than 6 inches from center to center. These cups were made of brass castings, and their leading features are best understood by reference to plate No. XII, where a plan and section are shown. As will be seen, the cups were circular in form, and consisted of two parts, which were riveted together. The lower part formed the neck of the cup and served to support the slotted top. The top was 1.69 inches in outside diameter and 0.75 inch high. It was cut with 24 slots, each 0.02 inch wide and 1.125 inches long. The total area of the slots in each cup was therefore 0.54

square inch. The diameter of the opening of the neck of the cups was 0.3125 inch, giving an area of 0.0767 square inch per cup. The total exit area of the tops of the cups was therefore 27.0 square inches and of the necks of the cups 3.835 square inches, a little less than that of a 2.25-inch pipe. It is the smaller of these two which controls the flow of the water.

Modifications of Strainer System.—On December 5 the original strainer cups were replaced by a new set, identical with the original cups, except that the slots were only 0.017 inch wide, and that in place of 24 slots there were 48 in the new cups. The total exit area remained the same with the new cups as with the old ones, being controlled by the neck of the cups. The exit area of the top of the new cups was larger than with the old, being 0.92 square inch per cup, or 46.0 square inches for the total.

Resistance of Strainer Cups.—Observation on the frictional resistance of the two sets of strainer cups were made, both for a direct flow as in filtration and a reverse flow as in washing. Similar tests were also made with the bottom of the cup alone. The results are summarized in the following tables:

Resistance of One Strainer Cup with Direct Flow.

Loss of Head. Feet.	Pounds of Water per Minute.		
	Bottom of Cup.	One Strainer Cup Complete with	
		Coarse Slots.	Fine Slots.
0.33	....	...	0.33
0.67	....	....	0.47
1.00	0.57	0.61	0.57
1.50	....	....	0.71
2.00	0.87	0.85	0.81
3.00	1.11	1.11	1.02

At the rate of flow of 100 million gallons per acre per day, the flow through each cup (fifty per 12.57 square feet)

was 4.06 pounds per minute. Interpolating the above observations, the loss of head at this rate in the bottom of the cup, the cup with the coarse slots and the one with the fine slots, were found to be 0.85, 0.79, and 0.85 feet, respectively, or practically the same. This indicated clearly that the main resistance in these cups was in the restricted neck of the bottom of the cups.

Resistance of One Strainer Cup with Reverse Flow.

Loss of Head. Feet.	Pounds of Water per Minute.		
	Bottom of Cup.	Complete Cup with	
		Coarse Slots.	Fine Slots.
17.25	....	....	2.34
17.00	2.37	....	....
15.80	....	2.28	....
12.25	....	....	1.98
11.00	1.92	....	....
10.25	....	1.92	....
8.00	1.65	....	....
7.20	....	1.59	....
6.50	....	...	1.44
4.30	1.23	....	....
4.00	....	....	1.11
3.25	....	1.14	....
2.20	0.57	....	....
1.90	....	....	6.75

These results are practically identical within the limits of error of observation. Actual interpolation gives the flow at 12.00 feet loss of head (the normal pressure on the bottom of the sand layer) as follows:

Bottom of cup	16.4	pounds	of water	per minute.
Complete cup with coarse slots	16.6	"	"	"
Complete cup with fine slots.....	17.1	"	"	"

Sand Layer.—The sand layer was 32 inches thick, or 30 inches deep above the top of the strainer cups, the actual effective thickness. The surface was an unbroken area 4 feet in diameter, or an area of 12.57 square feet.

Natural screened sand from Red Wing, Minnesota, was first used with this filter. This sand was quite free from clay and organic matter, but contained rather high numbers of bacteria, as will be seen from the following analyses:

Results of Examination of Red Wing Sand.

Parts per million of clay	1,860
Parts per million of nitrogen as albuminoid ammonia	7.4
Bacteria per gram	21,000

In order to remove any appreciable amounts of very fine material which might have remained from the screening, the sand was washed for one hour in place in the filter and the upper inch of the layer was then removed. Practically no change was effected by this process, as the sand had been very thoroughly screened. The sand was again washed for 15 minutes and was then placed in service.

Mechanical analyses of an average sample of the sand layer gave the following results:

Mechanical Analyses of Original Sand in Filter No. 20.

Percentage by weight finer than 2.18 millimeters	100.00
" " " 0.96 "	98.46
" " " 0.45 "	15.68
" " " 0.35 "	1.23
" " " 0.28 "	0.17
" " " 0.20 "	0.00
Effective size	0.42
Uniformity coefficient	1.80

Modifications of Sand Layer.—On December 5 the layer of sand from Red Wing was removed and replaced by a 30-inch layer of fine sand obtained from the bar in the Ohio River opposite Coney Island. Complete analyses of this sand have already been presented, and only the leading points will be repeated here:

Summary of Data on Coney Island Sand.

Effective size	0.22 millimeter.
Uniformity coefficient	1.5
Lime	1,800 parts per million.
Magnesia	2,400 " "
Iron	18,100 " "
Alumina	4,600 " "
Nitrogen as albuminoid ammonia*	26.0 " "
Clay*	900 " "
Bacteria*	30,000 per gram.

* After washing, as described below.

This sand (which had not been used before) was placed in the filter to a thickness of 30 inches over the strainers, and on December 6 was washed from below with filtered water for 23 minutes, using 250 cubic feet of water. About 2.5 inches of sand were added to compensate for settling, and the layer was again washed for 10 minutes, using 109 cubic feet of water.

On December 9 the fine sand was removed and replaced by 30 inches of the Red Wing sand. This sand had been exposed while wet to weather considerably below freezing. It was consequently as hard as a rock, and was broken with sledges and put into the tank. When immersed in water it thawed out readily, and after 30 minutes' washing no lumps of any appreciable size could be found. This sand was used from December 9 to December 14, when it was again replaced by 30 inches of the fine sand.

On December 22 one half of the layer of fine sand was removed, leaving a layer 15 inches thick above the strainers. The thickness of the layer was increased on December 24 to 20 inches, which was held to January 25, 1899, when operations were discontinued.

Agitating Device.

For the purpose of stirring the sand during washing an agitating device was provided. This device consisted of a vertical shaft from which the rake arms, two in number, were hung,

and a system of gears and pulleys for revolving, raising, and lowering this shaft. The main parts of this device are shown on the accompanying plates. Its operation was as follows:

Power was obtained by a 12-inch Pelton water wheel with a 4-inch driving pulley. From this wheel belts transmitted the power to a 24-inch pulley on a countershaft, and from a 6-inch pulley on the same shaft to the 9-inch pulley on the horizontal shaft of the machinery on the filter. As will be seen from the drawings (Plate XII), this horizontal shaft turned the vertical shaft and rakes by means of a bevel gear and pinion. In the vertical shaft was cut a double screw thread, 5 threads to the inch. This screw worked through a collar at A. This collar was loose in the framework of the device. Above and below this loose collar (at band C) were two other collars, each held in place by a strap, but free to move up and down the vertical shaft. Lugs on these collars and on the middle collar corresponded. A vertical slot in this shaft engaged at all times a lug in the upper collar, and forced this collar to turn with the shaft. There was no such lug in the lower collar which did not turn with the shaft, but remained fixed, except for vertical movements. Both the upper and lower collar were held in place by a pair of levers, which were pivoted, as shown in the drawing at D and E; the spring on the end of the upper lever tended at all times to raise the collars. By this arrangement the lower collar was kept in contact with the middle collar unless the action of the spring was overcome. Under these conditions the lug on the lower collar engaged the lug on the middle or threaded collar and prevented its turning around. When the vertical shaft was revolved it was forced to screw up or down, as the case might be, through the threaded collar. When the agitator was nearly down, the cap on the upper end of the shaft pressed both collars down, releasing the lower, and engaging

the upper collar with the middle or threaded collar. As the upper collar always revolved with the shaft, this action caused the middle collar to revolve and no further vertical movement of the shaft could take place. In lifting the rakes this action was simply reversed, except that until the cap was lifted about 1 inch from its lowest position the lower collar could not be engaged. In order to hold the middle collar until the vertical shaft had been raised this amount, it was necessary to insert a bar between the lug of the middle collar and the frame of the device, and hold this collar fixed until the shaft was high enough to engage the lower collar.

By this arrangement it was possible to raise and lower the rakes through a distance of 22 inches. If desired, the vertical movement could be stopped at any point by pulling down the upper collar by hand. For this purpose an extension of the upper lever was provided.

Rakes.—A casting fastened to the lower end of the vertical shaft held two rake arms. These arms were on parallel lines 3 inches apart, on opposite sides of the vertical shaft.

On each arm there were four rake teeth held to the arms by special castings. These teeth were spaced 5.5 inches from center to center. On one arm they were set 2.75, 8.25, 13.75, and 19.25 inches from the center of the central shaft, and on the other 5.5, 11, 16.5, and 22 inches from the center. By this arrangement the bed was thoroughly stirred in sections of not more than 2.75 inches in width. The rake teeth originally used were square bars 26 inches long.

On October 8 these rake teeth were removed and replaced by new teeth 26 inches long with four links of 0.375-inch chain on the end of each tooth, making the total length of the teeth 29.25 inches. The last link of these new teeth just touched the surface of the sand layer when the agitation was raised to its full height.

CHAPTER III.

MANNER OF OPERATION OF THE SUBSIDING TANKS AND THE EFFICIENCY OF PLAIN SUBSIDENCE FOR TWO TO THREE DAYS IN THE CLARIFICATION AND PURIFICATION OF OHIO RIVER WATER.

GENERAL PLAN OF OPERATION.

Four large steel tanks, each of a nominal available capacity of 100,000 gallons, were provided. These tanks were used for a preliminary clarification and purification of the river water before it was passed on to the filters. In the original design of the experimental purification plant it was decided to construct 15 filters of a total combined capacity of practically 100,000 gallons per 24 hours. The operation of the subsiding tanks was planned to suit the capacity of the filter plant, and the general method, starting with the tanks empty, was as follows:

Filling.—Each tank was filled from below through a 6-inch pipe supplying river water under about 48 feet head when the tank was empty. This operation required from 3.5 to 4.5 hours, filling to a depth of 33 feet, the variation in the rate of pumping at the Front Street Pumping Station having been apparently the controlling feature in the rate of filling. The lowest point of discharge (side outlet) in these tanks was 3 feet above the bottom, and the depth required for 100,000 gallons was 26.8 feet, making a total depth of 29.8 feet. In order to maintain more pressure at the end of the drawing, it was

originally planned to fill the tanks to 33 feet, and thus have 3.2 feet of pressure at the end of drawing.

Quiescent Subsidence. — As soon as the tank was full all valves were closed, and the water was allowed to remain in a quiescent condition until it was necessary to begin drawing. This period was planned to be 2.5 days.

Drawing. — Each tank was used in turn to supply the filters for 24 hours. As has been described, there were provided three outlet connections on each tank, placed at 3, 13, and 23 feet, respectively, from the bottom of the tank. These valves were used in order, the top valve being first opened, and the water allowed to drain until it stood about 1 foot above the opening, when the second valve was opened. In a corresponding manner the third valve was opened. By this procedure the water was drawn from the tank in sections about 10 feet deep at a maximum. This period of 24 hours gave an average additional subsidence of 12 hours for each lot, making the normal total period 3 days, or 72 hours.

Draining. — It was originally intended to drain out the water left in each tank, in order to keep the evidence upon each tankful of water as clearly defined as practicable.

Cleaning.—Each tank was to be cleaned by flushing before refilling, in order to avoid complications from disturbances of the accumulated sediment by the filling from below.

Refilling.—The operation of filling was the same as that of refilling, as originally planned, each tank to be drained and cleaned after using.

Later Modifications of the General Plan of Operation.

Several factors operated together to necessitate departures, more or less radical at times, from the original plan of operation, though in the main the general plan described above was

followed. Chief among these factors was the movement of the earth on the hillside on which these tanks were constructed. This movement reduced materially the supporting value of the pile foundations, and necessitated considerable work throughout the experiments to maintain the foundations in a safe condition for use. This movement was most pronounced at the south end of the platform, and was sufficient to cause the use of tank A to be a questionable procedure. On this account this tank was never used in regular operations.

From April 9 to 15 tank D alone was available for use. After this date, tanks B, C, and D were used regularly up to September 23. On this date the condition of the foundations of tank B necessitated its withdrawal temporarily from regular service. On October 10 tank B was again placed in service, but was not filled to more than one half of its depth.

This movement of the earth interfered considerably at times with the piping connections, and modifications in the plans were also necessitated thereby.

The second main cause for departure from the general plan of procedure was the introduction of new filters and of modifications in the operation of the filter plant, these changes requiring variations in the plans to obtain uniform periods of subsidence.

A factor which caused delays from time to time in the refilling of the tanks was the failure of the water supply in the particular force main (one of three) to which our inlet connection was made. This was due to the necessity of repairs at the Front Street Pumping Station, and several times it caused delays of more than a day.

The general operation of the subsiding tanks was for these reasons modified somewhat from time to time. A comprehensive view of the procedure can be obtained from

the following notes, which are presented in chronological order.

March 28 *to April* 10.—Two tanks were in service. They were used alternately, and the tanks were not drained before refilling. This gave a normal period of about 20 hours of quiescent subsidence, or a total average period of about 32 hours.

April 10 *to April* 15.—Tank C was taken out of service on April 10, leaving only tank D, which was drained, cleaned, and filled to about 30 feet. It was then used continuously, filling and drawing at the same time.

April 15 *to June* 3.—Three tanks were used in rotation during this period. The necessity of leveling the foundations, etc., caused delays more or less regularly in refilling the tanks of from 6 to 30 hours. Each tank was drained before refilling, and was generally cleaned unless the accumulated sediment was very light. The tanks were normally filled only to 31 feet in depth, in order to reduce the amount of water wasted in draining. Except in a few cases where a failure in the supply of water left a tank only partly filled, each tank was used for 24 hours' supply for the filters.

June 3 *to August* 5.—In order to increase the period of subsidence and restore it to as near the scheduled period of 72 hours as practicable, one third of the filters were closed down on June 3, reducing the amount of water handled per day to about 67,000 gallons. Each tankful therefore would give one and one half days' supply for the filters, and an average of 72 hours of subsidence could be readily obtained, unless some unusual delay prevented refilling. The three available tanks were used in rotation, drained each time and cleaned every other time.

August 5 *to August* 23.—Three tanks were used in rotation,

each for 32 hours' supply, the starting of filters Nos. 16 and 17 having increased the daily consumption. As nearly as practicable the tanks were filled each time on a schedule arranged to give 72 hours of average subsidence. The tanks were drained each time, but were not cleaned during this period, and the sediment was allowed to accumulate to study the effect of its solidification with reference to its removal.

August 23 to September 14.—Modifications in the operation of the filter plant reduced the amount of water required per day; and the subsiding tanks were ordinarily refilled promptly, thus increasing the period of subsidence to over 100 hours in several cases. During the latter part of this period special repair work on the piping system caused considerable delay and again reduced the period. The tanks were regularly drained, but were not cleaned, except that tank B was cleaned on September 9.

September 14 to September 23.—Further modifications in the filter plant were made on September 14; the quantity used per day was again restored to about 67,000 gallons; and each tankful of subsided water was used for 32 hours' supply. Increases over this amount, due to draining and refilling the supplementary subsiding basins, delays in refilling the tanks due to repairs in foundations, and delays for water, reduced the period of quiescent subsidence for nearly every lot. Each tank was drained, but not cleaned before refilling.

September 23 to October 10.—On September 23 it was decided that it was unsafe to use tank B for full loading without extended repairs of the foundations, and accordingly only two tanks were used during this period, each tank being filled to the full depth, 33.5 feet, and used until emptied to the lowest outlet. Modifications were made in the operation of the filters to reduce the daily consumption to about 50,000 gallons, and

each tankful lasted normally 48 hours. Delays due to draining, leveling of foundations, pipe repairs, etc., reduced the period of quiescent subsidence, however, so that an average of 72 hours could not be obtained. Tank C was cleaned on September 29 and tank D was cleaned October 5.

October 10 *to November* 23.—Three tanks were in use during this period. Tanks C and D were each used for 48 hours' supply for the filters, and tank B was used in such a manner as to maintain 72 hours' average subsidence for each lot, if no irregularities occurred. In order to maintain this arrangement, tank B was used for from 6 to 8 hours' supply, generally for every fifth lot. Tank B was cleaned at the beginning of this period, and the other tanks were drained regularly, but were not cleaned.

November 23 *to December* 20.—The necessity of repairing the piping connections to tank B caused its removal from regular service and only two tanks were operated. These two were used in rotation, and drained and refilled as rapidly as possible. Each tankful was drawn down to the regular limit, in order to obtain the maximum period of subsidence with the two tanks. Neither tank was cleaned during this period.

December 20 *to January* 25.—From December 20 to 25 tank B was in service to supplement tanks C and D, and maintain an average period of subsidence of 72 hours. The operation of the filter plant after this latter date required about 40,000 gallons a day, and tank B was therefore not required after December 25.

The other two tanks were used alternately for 48 hours' supply for the filters, and were drained and refilled as rapidly as possible each time. Tank C was cleaned on December 29 and tank D was cleaned on January 4. These tanks were not cleaned out again until after the close of operations on January 25, 1899.

DESCRIPTION OF TABLE SHOWING THE RESULTS OF OPERATION OF THE SUBSIDING TANKS FOR PLAIN SUBSIDENCE OF OHIO RIVER WATER.

In the following table are presented all of the leading results of operation of the subsiding tanks, arranged and averaged by lots, and also the total averages for the entire investigations. The leading data presented may be briefly described as follows :

Lot.—Each time a tank was filled, the water which it contained was given a serial lot number, and was so designated in its passage through the system.

Collection of Samples.—Samples of river water (one chemical and two bacterial) were collected during each filling of a tank, and when the tank was about half full. At 8 A. M., 4 P. M., and 12 P. M. every day, bacterial and chemical samples were collected of the subsided water as it passed to the filters. All of the bacterial samples were analyzed, and at times of muddy water each chemical sample of a lot was examined partially. More complete chemical analyses were made of the mixture of the several separate portions of each lot.

Dates.—The date of filling and the date and hour when the lot was first turned on to the filters are recorded. The beginning of use of any lot was the end of use of the preceding lot.

Stage of River.—The stage of the river at 6 P. M. on the date of filling each lot is recorded.

Period of Subsidence.—The period of subsidence was taken as the time from the end of filling of the tank (or lot) to the middle of the period of drawing.

Suspended Matter. — The amount of suspended matters in the river water at the time of filling each lot is recorded; and the amount of these matters in each portion of the subsided water examined, and their average, are also given. The results

of the separate portions are recorded in the order of collection (under columns marked A, B, C, etc.) of the samples.

Organic Matter.—The total nitrogenous and total carbonaceous matter in the river water and in the average subsided water are recorded in parts per million, as indicated by the results of the determinations of nitrogen as albuminoid ammonia and of oxygen consumed, respectively.

Bacteria.—The bacteria per cubic centimeter in the river water (average of two samples) and in the subsided water are given. In the case of subsided water the separate determinations are stated in the order of collection of the samples (under columns marked A, B, C, etc.), and their average is also recorded.

Efficiencies.—The efficiency of removal by plain subsidence of suspended matters, organic matters, and bacteria, respectively, are given. These efficiencies were calculated in the usual manner by dividing the difference between the amount in the river water and the amount in the average subsided water by the amount in the river water.

Special studies were also made of the effect of subsidence upon the dissolved constituents of the water, and the results are stated in a section following the tables.

Methods of Analysis.—These were the same as outlined for the river water (page 25). It only remains to be added that a diaphanometer was used to much advantage in estimating promptly the weight of suspended matter. There was noted the depth of a column of water which obscured a cross (1-mm lines) on a diaphragm at the bottom of a 1.37-inch tube, when viewed with a light from a Welsbach burner, reflected by mirrors and intensified by lenses. By the use of a formula these depths were converted into parts per million of suspended matter.

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Date, 1898. Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
1	March 24	March 28, 4:00 PM	50.7	102.3	534	169	153	....	161
2	" 25	" 29, 10:00 PM	52.7	118.6	505	124	111	....	117
3	" 29	" 30, 11:00 PM	61.4	41.8	334	185	157	....	171
4	" 31	April 1, 1:00 AM	58.6	34.3	140	91	88	78	86
5	April 1	April 2, 3:00 AM	56.5	34.4	126	76	52	60	63
6	" 2	" 3, 5:00 AM	54.1	34.2	118	97 59	70 52	70	69
7	" 3	" 4, 6:00 AM	51.2	32.9	182	107	65	87	86
8	" 4	" 5, 8:00 AM	47.6	31.0	152	76	70	65	73
9	" 5	" 6, 8:00 AM	42.9	33.3	155	21	35	34	30
10	" 6	" 7, 8:00 AM	37.6	31.7	312	61	56	52	56
11	" 7	" 8, 8:00 AM	32.3	31.8	283	91	....	....	91
12	" 8	" 9, 8:00 AM	28.6	32.3	158	52	....	....	52
13	" 9	" 10, 8:00 AM	25.6	24.0	390	92	95	..	93
14	" 10	" 11, 8:00 AM	23 7	24.0	164	62	71	70	68
15	" 11	" 12, 8:00 AM	22.0	24.0	191	67	51	74	64
16	" 12	" 13, 8:00 AM	20.5	24.0	154	79	....	....	79
17	" 13	" 14, 8:00 AM	19.4	24.0	194	133	55	47	78
18	" 14	" 15, 8:00 AM	19.3	25.4	97	39	38	22	33
19	" 15	" 16, 9:00 AM	20.0	32.4	81	48	38	....	43
20	" 16	" 17, 9:00 AM	20.6	31.0	115	28	28	22	25
21	" 17	" 18, 9:00 AM	20.4	32 1	88	28	15	14	19
22	" 18	" 19, 9:00 AM	20.3	29.8	109	35	23	28	29
23	" 18	" 20, 9:00 AM	20.3	49.0	109	33	45	34	37
24	" 20	" 21, 9:00 AM	21.3	28.0	251	47	29	27	34
25	" 20	" 22, 9:00 AM	21.3	55.9	251	39	34	24	32
26	" 21	" 23, 9:00 AM	20.9	49.0	67	32	....	....	32
27	" 22	" 24, 9:00 AM	20.8	56.1	77	23	....	....	23
28	" 23	" 25, 9:00 AM	20.1	50.1	75	23	28	26	26

Efficiency of the Subsiding Tanks.

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				Serial Lot.
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed.			Subsided Water.				Suspended Matter.	Organic Matter.		Bacteria.	
River Water.	Subsided Water.	River Water.	Subsided Water.	River Water.	A.	B.	C.	Average.		Nitrogenous.	Carbonaceous.		
.472	.238	7.9	5.0	24,900	16,600	.....	.....	16,600	70	50	37	33	1
.414	.239	10.1	5.7	12,200	3,900	3,900	9,300	5,700	77	43	46	53	2
.398	.242	8.6	4.9	13,500	13,500	8,100	6,900	9,500	49	39	43	30	3
260	.198	6.3	3.6	14,300	5,900	3,400	4,800	4,700	39	24	43	67	4
.216	.166	5.2	3.6	8,800	5,700	5,700	6,800	6,100	50	23	31	31	5
.200	.166	5.6	3.8	27,600	4,100	5,000	3,100	4,100	42	17	32	85	6
.260	.166	4.6	3.1	14,100	4,200	3,900	2,700	3,600	58	36	33	74	7
.220	.180	5.5	3.7	6,900	4,400	2,700	3,400	3,500	54	18	33	49	8
.282	.176	4.9	2.6	7,200	2,700	3,200	4,300	3,400	81	33	47	53	9
.330	.148	8.0	4.3	7,900	3,000	2,600	2,500	2,700	82	55	46	66	10
.256	.172	5.9	3.2	6,600	2,200	2,000	.....	2,100	68	33	46	68	11
.202	.138	4.9	2.2	3,200	2,800	.....	.....	2,800	67	32	55	13	12
.316	.196	7.2	3.2	4,400	4,000	3,600	.....	3,800	76	38	56	14	13
.202	.142	5.0	2.3	5,600	2,000	1,800	.....	1,900	59	30	54	66	14
.260	.110	6.4	2.6	4,800	1,800	2,300	2,500	2,200	66	58	59	54	15
.208	.122	4.9	2.7	5,200	2,100	2,700	.....	2,400	49	41	45	54	16
.150	.110	4.4	2.7	6,900	2,100	1,900	2,800	2,300	60	27	39	67	17
.146	.104	3.7	2.1	4,400	3,400	3,300	3,800	3,500	66	29	43	21	18
.146	.080	3.5	1.8	3,700	2,600	2,800	.....	2,700	47	45	49	27	19
.130	.076	3.1	1.8	6,000	3,800	5,000	.....	4,400	78	42	42	27	20
.110	.080	3.0	1.6	6,500	4,100	3,700	3,200	3,700	78	27	47	43	21
.106	.094	2.6	1.7	12,700	4,200	5,100	2,300	3,900	73	11	35	69	22
.106	.078	2.6	1.7	12,700	3,500	8,600	5,700	5,900	66	26	35	54	23
.198	.088	4.5	1.8	12,500	6,400	5,100	5,500	5,700	86	56	60	54	24
198	.080	4.5	1.6	12,500	7,000	6,100	5,800	6,300	87	60	64	50	25
.110	.092	2.9	2.0	15,800	6,300	5,900	.....	6,100	52	16	31	61	26
.127	.084	3.0	1.8	14,900	7,200	7,900	8,000	7,700	70	34	40	48	27
.116	.096	2 5	1.8	14,900	5,000	6,300	4,700	5,300	65	17	28	64	28

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
29	April 25	April 26, 9:00 AM	18.8	30.1	251	37	35	33	35
30	" 25	" 27, 9:00 AM	18.8	49.5	251	18	21	18	19
31	" 26	" 28, 9:00 AM	17.0	52.3	58	34	31	20	28
32	" 27	" 29, 9:00 AM	16.5	49.0	72	12	8	8	9
33	" 28	" 30, 9:00 AM	20.8	46.8	223	37	....	....	37
34	" 29	May 1, 9:00 AM	26.3	55.4	290	37	....	....	37
35	" 30	" 2, 9:00 AM	28.5	55.3	446	58	94	88	80
36	May 2	May 3, 9:00 AM	27.0	28.4	274	47	28	39	38
37	" 2	" 4, 9:00 AM	27.0	47.3	274	21	....	....	21
38	" 3	" 5, 9:00 AM	24.4	50.0	122	19	....	....	19
39	" 5	" 6, 9:00 AM	19.2	25.7	137	22	30	17	23
40	" 6	" 7, 9.00 AM	16.9	33.2	147	30	....	....	30
41	" 6	" 8, 9:00 AM	16.9	53.1	147	24	....	....	24
42	" 7	" 9, 9:00 AM	21.6	52.4	419	126	131	131	129
43	" 8	" 10, 9:00 AM	23.3	55.0	312	88	82	77	82
44	" 9	" 11, 9:00 AM	24.3	52.5	305	66	69	68	68
45	" 10	" 12, 9:00 AM	24.8	53.2	312	57	56	46	52
46	" 11	" 13, 9:00 AM	25.0	49.2	207	70	28	26	41
47	" 12	" 14, 9:00 AM	24.1	54.1	250	53	....	....	53
48	" 13	" 15, 9:00 AM	24.0	50.6	216	68	....	....	68
49	" 14	" 16, 9:00 AM	22.5	53.2	122	37	41	31	36
50	" 16	" 17, 9:00 AM	20.9	28.2	279	69	55	....	62
51	" 17	" 18, 3:00 AM	20.1	26.0	133	60	52	48	53
52	" 17	" 19, 3:00 AM	20.1	44.4	133	41	54	56	50
53	" 18	" 20, 3:00 AM	20.0	47.1	99	53	50	49	51
54	" 19	" 21, 4:40 AM	24.5	57.6	171	43	39	46	43
55	" 20	" 22, 3:15 AM	27.3	44.9	394	111	....	....	111
56	" 21	" 23, 5:35 AM	28.0	52.1	396	141	135	132	136

Efficiency of the Subsiding Tanks—(Continued).

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed.			Subsided Water.					Organic Matter.			
River Water.	Subsided Water.	River Water.	Subsided Water.	River Water.	A.	B.	C.	Average.	Suspended Matter.	Nitrogenous.	Carbonaceous.	Bacteria.	Serial Lot.
.298	.130	6.2	2.8	20,800	12,600	12,600	11,400	12,200	86	56	55	41	29
.298	.124	6.2	2.6	20,800	8,600	11,600	8,500	9,600	92	58	58	54	30
.128	.114	3.0	2.4	15,000	4,900	6,700	6,500	6,000	52	11	20	60	31
.148	.122	3.8	2.5	12,400	4,500	4,000	3,900	4,100	87	18	34	67	32
.236	.106	5.1	2.2	21,400	8,900	.....	.....	8,900	83	55	57	58	33
.288	.124	5.8	2.7	15,000	4,800	4,200	.....	4,500	87	57	53	70	34
.386	.194	7.2	4.0	13,500	5,900	6,200	6,400	6,200	82	50	44	54	35
.284	.120	7.6	3.2	8,200	3,400	3,500	2,900	3,300	86	58	58	60	36
.284	.116	7 6	2.8	8,200	2,300	2,200	1,800	2,100	92	59	63	74	37
.196	.122	5.0	2.7	5,600	3,200	2,700	2,700	2,900	84	38	46	48	38
.186	.116	4.3	2.7	4,100	2,400	2,000	1,200	1,900	83	38	37	54	39
176	134	4.0	2.8	4,600	2,700	.....	.....	2,700	80	24	30	41	40
.176	.118	4.0	2.7	4,600	1,900	2,800	.....	2,300	84	33	33	50	41
410	.218	6.9	4.4	33,000	14,400	17,700	13,700	15,300	69	47	36	54	42
362	.184	6.5	3.9	54,600	13,500	12,000	11,100	12,200	74	49	40	78	43
.356	.178	6.4	3.9	16,800	9,100	7,800	7,000	8,000	78	50	39	52	44
.302	.168	6.9	3.1	10,000	3,900	4,700	.....	4,300	83	44	55	57	45
.274	.132	5.6	2.8	6,800	5,200	2,000	2,100	3,100	80	52	50	54	46
.280	.136	6.0	3.0	6,600	4,000	.....	.....	4,000	79	53	50	39	47
.274	.158	5.8	3.7	14,500	5,000	4,000	.....	4,500	69	42	36	69	48
210	.134	4.9	2.8	6,400	4,300	2,700	2,100	3,000	70	36	43	53	49
.248	.154	4.8	2.5	6,900	2,200	2,000	1,900	2,000	78	38	48	71	50
.208	.114	4.4	2.8	7,500	2,200	3,000	.....	2,600	60	45	36	65	51
208	.122	4.4	2.6	7,500	2,300	1,900	1,400	1,900	62	41	41	75	52
.176	.108	3.5	2.2	7,400	2,300	2,100	1,600	2,000	48	39	37	73	53
.238	.128	4.6	2.5	7,900	1,500	1,400	.....	1,500	75	46	46	81	54
.330	.206	7.2	4.3	10,300	2,500	.....	.....	2,500	72	38	40	76	55
358	.208	7.5	4.0	5 500	2,700	1,700	2,000	2,100	66	42	47	62	56

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
57	May 22	May 24, 6:30 AM	28.0	57.5	310	108 / 88	106	84	95
58	" 23	" 25, 8:55 AM	27.0	54.8	322	79	69	70	73
59	" 24	" 26, 9:00 AM	25.0	53.7	218	72	66	55	64
60	" 25	" 27, 9:00 AM	23.5	51.0	109	46	51	52	50
61	" 26	" 28, 9:00 AM	24.5	52.8	313	82	....	....	82
62	" 27	" 29, 8:45 AM	25.8	50.8	205	62	....	....	62
63	" 28	" 30, 8:45 AM	25.3	51.0	173	58	49	....	51
64	" 29	" 31, 9:00 AM	23.8	55.8	182	58	64	50	57
65	" 30	June 1, 9:00 AM	22.0	55.3	154	40	45	35	40
66	" 31	" 2, 9:00 AM	20.3	52.3	204	54	56	43	51
67	June 1	June 3, 8:00 AM	18.8	49.1	193	39	44	41	41
68	" 2	" 4, 8:00 AM	17.0	60.0	184	40	29	22	30
69	" 3	" 5, 8:00 PM	15.9	67.8	217	56	48	31	45
70	" 4	" 7, 8:00 AM	14.7	78.5	124	50	40	25	38
71	" 6	" 8, 8:00 PM	13.5	60.3	149	28	12	12	16
72	" 7	" 10, 8:00 AM	11.8	81.7	72	20	17	12	16
73	" 9	" 11, 8:00 PM	10.3	70.0	64	11	18	14	14
74	" 10	" 13, 8:00 AM	9.8	79.2	54	17	16	18	17
75	" 12	" 14, 8:00 PM	9.0	80.5	45	11	14	12	12
76	" 13	" 16, 8:00 AM	8.6	82.1	74	16	6	9	10
77	" 15	" 17, 8:00 PM	8.1	70.7	79	17	14	7	13
78	" 16	" 19, 8:00 AM	8.1	79.6	35	12	. .	....	12
79	" 18	" 20, 8:00 PM	9.1	67.7	39	5	12	6	8
80	" 19	" 22, 8:00 AM	10.3	82.0	37	10	6	....	8
81	" 20	" 23, 8:00 PM	11.7	69.0	68	7	9	3	6
82	" 24	" 25, 8:00 AM	13.3	31.0	197	71	39	26	45
83	" 24	" 26, 8:00 PM	13.3	56.0	191	75	67	59	67
84	" 25	" 28, 8:00 AM	13.9	78.0	151	51	45	39	45

Efficiency of the Subsiding Tanks—(Continued).

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				Serial Lot.
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed.		River Water.	Subsided Water.				Suspended Matter.	Organic Matter.		Bacteria.	
River Water.	Subsided Water.	River Water.	Subsided Water.		A.	B.	C.	Average.		Nitrogenous.	Carbonaceous.		
.356	.204	6.6	3.4	6,700	2,000	2,400	2,100	2,400	69	48	48	64	57
.362	.142	6.9	3.0	6,200	1,800	2,400	2,300	2,200	77	61	57	65	58
.276	.144	5.9	2.8	6,400	2,000	2,400	2,900	2,400	71	48	53	62	59
.174	.132	4.0	2.8	3,700	2,200	1,600	.....	1,900	54	24	30	49	60
.298	.172	6.1	3.2	8,400	2,900	.....	.....	2,900	74	42	48	65	61
.242	.130	4.8	2.7	6,900	3,600	.....	.....	3,600	70	46	44	48	62
.230	.112	5.2	2.9	6,000	1,700	.....	.....	1,500	71	51	44	75	63
.252	.162	5.5	3.0	7,700	1,400	1,400	900	1,200	69	36	45	84	64
.212	.128	4.8	3.3	4,900	1,200	1,100	1,000	1,100	74	40	31	78	65
.300	.130	5.5	3.1	6,100	1,700	1,000	1,200	1,300	75	57	44	79	66
.258	.132	5.5	2.7	5,800	750	1,100	600	800	79	49	51	86	67
.266	.128	5.2	2.8	5,600	850	900	1,000	900	84	52	46	84	68
.242	.124	5.1	2.8	4,100	1,100 600	500	500	700	79	49	45	83	69
.218	.120	4.1	2.6	4,800	600 700	500 500	600	600	69	45	37	88	70
.216	.106	4.4	2.2	6,300	1,200 800	900 600	700	800	89	51	50	87	71
.186	.112	3.2	2.2	5,400	500 500	1,200	600	700	78	40	31	87	72
.148	.124	2.7	1.9	4,900	900	500	.....	700	78	16	30	86	73
.138	.104	2.8	1.7	3,600	500 900	1,400	600	1,100	69	25	39	69	74
122	.100	2.4	1.6	5,200	900 500	200	500	500	73	18	33	90	75
.166	.108	2.5	1.8	6,600	100 150	250	200	200	86	35	28	97	76
.148	.106	2.5	1.6	6,000	300 350	300 100	100	250	84	28	36	96	77
.134	.090	2.2	1.5	1,200	110 115	110	75	100	66	33	32	92	78
.146	.094	2.2	1.5	4,700	180 85	160 110	95	125	79	36	32	97	79
.174	.086	2.3	1.6	3,900	110 110	130	75	110	78	51	30	97	80
.194	.098	2.7	1.7	5,700	300 300	160 180	300	250	91	50	37	96	81
.212	.136	4.6	2.7	12,600	4,100 3,800	4,500	4,700	4,300	77	36	41	66	82
.248	.188	4.9	2.4	8,200	1,900 1,200	1,400 750	1,100	1,300	65	44	51	84	83
.196	.128	4.4	2.3	10,400	2,100 1,100	1,500	900	1,400	70	35	48	87	84

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
85	June 28	June 29, 8:00 PM	10.9	46.3	154	78	73	57	69
86	" 29	July 1, 8:00 AM	10.6	37.7	243	164	130	107	134
87	" 30	" 2, 8:00 PM	10.1	85.5	221	100	97	66	88
88	July 1	July 4, 8:00 AM	9.7	83.6	194	78	71	56	68
89	" 2	" 5, 8:00 PM	9.8	85.5	111	46	36	29	37
90	" 4	" 7, 8:00 AM	9.0	84.8	76	29	21	14	23
91	" 7	" 8, 8:00 PM	8.4	43.7	165	105	90	87	94
92	" 8	" 10, 8:00 AM	8.3	48.8	78	38	26	34	33
93	" 9	" 11, 8:00 PM	8.7	68.3	94	41	38	34	38
94	" 10	" 13, 8:00 AM	8.3	73.8	76	41	25	19	28
95	" 13	" 14, 8:00 PM	6.9	48.3	58	16	16	17	16
96	" 14	" 16, 8:00 AM	6.7	49.7	52	21	11	7	13
97	" 16	" 17, 8:00 PM	6.2	49.8	81	22	23	8	18
98	" 16	" 19, 8:00 AM	6.2	80.7	81	10	8	7	8
99	" 17	" 20, 8:00 PM	6.9	81.7	70	27	25	18	23
100	" 19	" 22, 8:00 AM	7.5	84.2	244	86	77	71	78
101	" 20	" 23, 8:00 PM	8.2	84.8	370	183	183	192	187
102	" 22	" 25, 8:00 AM	9.2	77.3	274	120	120	105	113
103	" 23	" 26, 8:00 PM	9.5	85.3	175	74	69	55	66
104	" 25	" 28, 8:00 AM	9.0	78.2	173	91	62	57	70
105	" 27	" 29, 8:00 PM	11.0	62.7	609	201	200	176	192
106	" 28	" 31, 8:00 AM	10.3	79.2	924	347	322	277	315
107	" 29	Aug. 1, 8:00 PM	10.8	84.9	271	87	75	65	76
108	Aug. 1	Aug. 3, 8:00 AM	11.2	48.6	394	220	186	162	189
109	" 2	" 4, 8:00 PM	12.0	66.5	324	105	91	77	91
110	" 3	" 6, 8:00 AM	12.1	83.9	316	98	91	73	87
111	" 5	" 7, 8:00 PM	12.2	65.9	336	124	117	98	113
112	" 6	" 9, 4:00 AM	12.6	75.5	405	189	176	162	176

Efficiency of the Subsiding Tanks—(Continued).

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				Serial Lot.
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed.		River Water.	Subsided Water.				Suspended Matter.	Organic Matter.		Bacteria.	
River Water.	Subsided Water.	River Water.	Subsided Water.		A.	B.	C.	Average.		Nitrogenous.	Carbonaceous.		
.208	.114	3.9	2.4	7,000	2,100 1,400	1,800 1,200	1,100	1,500	55	45	38	79	85
.252	.196	4.9	3.3	10,500	1,300 1,700	2,800	2,100	2,000	45	22	33	81	86
.228	.160	4.8	3.3	12,300	1,300 600	1,600	1,800	1,300	60	30	31	89	87
.242	.132	4.0	2.6	6,700	1,400	1,700	750	950	65	45	35	86	88
.184	.132	3 6	2.5	8,100	3,700 3,000	3,200	3,300	3,300	67	28	31	59	89
.190	.120	3.4	2.7	5,000	550 450	650	450	500	70	37	21	90	90
.178	.140	3.5	2.6	9,200	750 325	750 210	475	500	43	21	26	95	91
144	.118	2.7	2.4	8,900	2,200 600	1,200	900	1,200	58	18	11	87	92
.184	.132	2.7	2.3	6,600	1,800 1,400	1,200 1,200	1,900	1,500	60	28	15	77	93
.144	.114	3.1	2.1	3,500	750 800	700 650	550	700	63	21	32	80	94
.150	110	2.8	2.1	9,800	350 500	650	550	500	72	27	25	95	95
144	.122	2 8	2.0	17,900	1,000	1,100	700	950	75	15	29	95	96
.141	.122	3.0	2.2	11,000	400 450	550	650	500	78	15	27	95	97
.144	.106	3.0	2.2	11,000	4,000 1,800	3,500	2,100	2,800	91	26	27	75	98
.152	.118	2.6	2.3	7,900	850 1,100	700 800	650	800	67	22	11	90	99
.254	.126	3.8	2.5	16,700	3,100	5,800	5,500	4,800	67	50	34	71	100
.308	224	5.8	3.4	25,100	10,100 4,800	6,700 5,200	6,600	6,700	50	27	41	73	101
.270	.198	4.8	3.5	16,600	2,900 2,300	4,100	3,000	3,100	67	27	27	81	102
.240	.130	3.9	2.8	16,800	4,900 2,700	3,600 1,900	2,800	3,200	62	46	28	83	103
.240	.148	4.1	2.6	59,700	6,500 2,800	11,300	6,200	6,200	60	38	37	90	104
.521	.214	7.1	3.6	16,900	3,800 2,200	3,300 2,100	2,300	2,700	68	59	49	84	105
.624	.268	9.3	4.2	28,000	18,900	9,900	5,300	9,700	66	57	55	81	106
258	.147	5.2	2.7	12,500	900 1,100	1,100 650	1,100	1,000	72	43	48	92	107
.316	.204	5.3	3.6	12,100	5,600 2,200	3,500	2,300	3,400	52	35	32	72	108
.360	.154	5.3	2.8	11,100	2,500 1,500	1,700 2,000	1,700	2,000	72	57	47	82	109
.314	.150	5.0	3.1	11,400	2,000 1,100	1,000	1,000	1,300	72	52	38	89	110
.364	190	5.6	3.1	10,100	5,500 4,400	5,700	2,300	4,500	66	48	45	55	111
318	.192	5 8	3.3	9,700	3,000 3,700	6,600 3,800	3,400	4,100	57	40	43	58	112

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
113	Aug. 7	Aug. 10, 12:00M	14.3	74.8	867	246	213	215	225
114	" 9	" 11, 8:00PM	21 0	73.3	1,255	292	....	....	292
115	" 10	" 13, 4:00AM	21.8	72.5	800	224 208	218 200	214	212
116	" 12	" 14, 8:00PM	34.2	79.5	1,321	255 226	257	256	248
117	" 13	" 16, 8:00AM	39.2	84.4	641	211	215	172	199
118	" 15	" 17, 12:00M	36.7	49.0	182	124	122	119	122
119	" 16	" 18, 2:00PM	32.6	59.6	379	107 89	97	93	96
120	" 18-19	" 19, 11:10PM	23.8	36.6	681	181 142	160 116	151	150
121	" 19	" 21, 10:00AM	20.7	67.7	504	148 136	142	120	136
122	" 20	" 22, 11:00PM	18.2	83.5	533	166 132	116 105	102	124
123	" 22	" 24, 11:30AM	14.8	76.0	277	81 96	79 69	80 61	78
124	" 23	" 26, 1:15PM	15.5	114.4	256	58 52 58	66 53 63	67 54 63	59
125	" 24	" 29, 9:15AM	19.1	136.4	537	125 111	119 108	114 102	112
126	" 27	" 31, 8:40AM	19.2	102.8	429	73 62	71	66	68
127	" 30	Sept. 1, 9:50PM	11.5	66.8	205	64 59	55 60	53	58
128	" 31	" 3, 9:20AM	11.1	80.6	138	39 37	46 40	31	39
129	Sept. 2	Sept. 5, 1:30AM	9.8	75.2	82	27 22	32	26	27
130	" 3	" 6, 1:00PM	9 7	93.4	75	11 11	12 10	13 9	11
131	" 5	" 8, 9:40AM	9.6	97.0	69	12 9	9 5	8	9
132	" 9	" 10, 6:00AM	8.0	31.9	39	21 13	17 11	11 5	13
133	" 10	" 12, 2:45AM	8.7	60.4	29	8 8	9	8	8
134	" 13	" 13, 7:00PM	9.0	85.2	46	8	8	8	8
135	" 13	" 14, 9:00PM	9.0	44.4	57	23 18	22	20	21
136	" 14	" 15, 11:45PM	8.3	50.5	28	12	11	11	11
137	" 15	" 17, 6:45AM	7.7	55.9	36	14 12	12	11	12
138	" 16	" 18, 4:30PM	7.3	61.7	130	....	....	....	33
139	" 17	" 20, 12:30AM	7.0	72.3	42	....	....	....	11

Efficiency of the Subsiding Tanks—(Continued).

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				Serial Lot.
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed.			Subsided Water.					Organic Matter.			
River Water.	Subsided Water.	River Water.	Subsided Water.	River Water.	A.	B.	C.	Average.	Suspended Matter.	Nitrogenous.	Carbonaceous.	Bacteria.	
.560	.202	9.3	3.7	13,100	4,700 2,600	4,700	3,800	4,000	74	64	60	69	113
.820	.258	13.1	4.9	32,500	5 100 4,700	3,900	2,100	4,000	77	69	63	88	114
.580	.216	11.1	4.7	28,100	3,600	6,100	.....	4,800	74	63	58	83	115
860	.244	16.8	5.3	10,800	3,700 2,200	2,800 2,000	2,800	2,700	81	72	68	75	116
.490	.210	10.3	5.0	5,900	3,200	3,200	2,900	3,100	69	57	51	47	117
.230	.174	5.6	3.8	5,400	1,500	1,300	2,000	1,600	83	24	32	70	118
.396	.190	8.1	5.4	4,000	2,000 1,800	1,700	1,500	1,600	75	52	33	60	119
.590	.194	9.1	4.5	15,100	9,000	4,900	4,800	6,200	78	67	51	59	120
.430	.210	8.7	4.1	22,000	4,300	3,300	3,500	3,700	73	51	53	83	121
.390	.192	9.1	4.4	19,900	7,200 3,200	3,600 3,100	3,800	4,200	77	51	52	79	122
.286	.154	6.5	3.9	5,500	1,800 1,100	1.500 1,000	1,000 900	1,200	72	46	40	78	123
.264	.156	6.5	3.5	5,700	1,000 1,600	900 1,600	1,200 1,100	1,500	78	41	46	74	124
450	.166	7.8	3.6	6,000	1,300 1,600	1,500 1,700	1,800 1,200	1,500	79	63	54	75	125
.474	.178	8.1	3.4	9,300	3,200 1,100	1,900	1,900	2,000	84	62	58	78	126
.268	.158	6.4	4.0	4,500	3,000 2,000	2,500 1,300	1,800	2,100	72	41	38	53	127
.218	.170	5.5	4.0	6,200	3,300	2,000	.....	2,600	72	22	27	58	128
.198	.144	4.3	3.8	5,900	1,000	1,200	900	1,000	67	27	12	83	129
.178	.142	3.8	3.2	7,200	400 500	475 700	450 650	500	85	20	15	93	130
.184	.126	3.5	2.9	5,600	1,200 650	800 325	600	700	87	32	17	88	131
.194	.136	3.1	2.7	11,100	3,400	1,600	600	1,900	67	30	13	83	132
180	.122	2.9	2.1	6,800	500 140	375 240	150	275	72	32	28	96	133
.190	.126	3.1	2.2	8,200	350	230	200	250	83	34	29	97	134
.190	.116	2.4	1.9	9,400	4,300	3,200	2,600	3,400	63	39	21	64	135
.146	114	2.6	1.8	14,800	2,200 1,400	1,600	1,600	1,700	61	22	31	89	136
140	116	2.4	2.2	10,100	1,300	4,200	.....	2,800	67	17	8	72	137
.210	.114	3.7	2.2	8,400	2,200 1,300	2,200	1,500	1,800	75	46	41	79	138
.144	.114	2 6	2.2	12,400	3,000 1.000	1,800	1,300	1,800	74	21	15	85	139

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
140	Sept. 18	Sept. 21, 8:30 AM	6.9	74.9	28	....	....	....	10
141	" 21	" 22, 4:30 PM	6.0	40.6	241	....	....	....	27
142	" 22	" 24, 5:00 AM	6.0	54.0	257	....	....	....	30
143	" 23	" 25, 8:30 AM	5.8	61.2	123	....	....	....	7
144	" 26	" 27, 8:30 AM	5.1	46.3	81	....	....	....	21
145	" 27	" 29, 7:45 AM	5.5	64.3	117	....	....	....	26
146	" 29	Oct. 1, 5:55 AM	8.7	58.5	69	....	....	....	9
147	Oct. 1	Oct. 3, 8:30 AM	7.0	65.0	40	....	....	....	7
148	" 3	" 5, 8:30 AM	5.3	62.2	32	....	....	....	11
149	" 5	" 7, 8:30 AM	4.5	64.4	48	....	....	....	15
150	" 7	" 9, 8:30 AM	4.9	64.3	39	....	....	....	8
151	" 9	" 11, 8:20 AM	5.5	66.8	27	....	....	....	6
152	" 10	" 13, 8:00 AM	7.5	68.5	51	....	....	....	13
153	" 11	" 13, 8:30 PM	8.0	71.7	63	....	....	....	17
154	" 13	" 15, 8:30 PM	7.0	70.2	46	....	....	....	20
155	" 14	" 17, 6:00 PM	6.6	80.0	60	....	....	....	27
156	" 15	" 18, 3:10 AM	6.3	72.2	24	....	....	....	8
157	" 17	" 19, 8:30 PM	6.4	69.4	38	....	....	....	10
158	" 19	" 21, 8:00 PM	6.9	70.3	40	....	....	....	16
159	" 20	" 22, 8:00 AM	6.7	70.9	41	....	....	....	12
160	" 22	" 24, 6:45 AM	8.8	71.3	35	....	....	....	16
161	" 23	" 26, 7:00 AM	11.5	84.2	55	....	....	....	10
162	" 24	" 26, 8:30 PM	13.4	69.4	144	56 47	54 45	50 38	48
163	" 26	" 28, 4:20 PM	23.9	66.5	599	114 119	124 114	124	123
164	" 27	" 30, 2:45 PM	25.0	67.1	414	....	....	....	113
165	" 28	" 30, 11:20 PM	24.0	72.5	369	78 76 70	81 74	78 74	74
166	" 30	Nov. 2, 12:15 AM	20.0	70.5	215	77 76	72 79	76 66	69

Efficiency of the Subsiding Tanks—(Continued).

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				Serial Lot.
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed.			Subsided Water.					Organic Matter.			
River Water.	Subsided Water.	River Water.	Subsided Water.	River Water.	A.	B.	C.	Average.	Suspended Matter.	Nitrogenous.	Carbonaceous.	Bacteria.	
.124	.118	2.5	1.8	21,600	1,400 550	1,200	1,100	1,100	64	5	28	95	140
.312	.122	5 5	2.1	21,000	8,400 2,200	6,000	4,000	5,100	89	61	62	71	141
.292	.126	5.3	2.5	26,900	10,400	11,900	.....	11,200	88	57	53	58	142
.226	.120	4.0	1.9	15,600	2,100 900	1,800 350	900	1,200	94	47	53	92	143
.174	.122	2.9	2.1	15,500	1,000 1,500 1,100	3,300 2,200	2,200 1,000	1,800	74	30	28	88	144
.222	.126	3.2	2.2	27,800	3,300 1,300	2,300 900	1,400	1,800	78	43	31	94	145
142	.114	2.4	1.6	11,200	1,800 350	1,000	550	950	87	20	33	92	146
.142	.098	2.2	1.7	13,000	1,700 1,000	2,300 1,200	2,000 750	1,500	82	31	23	88	147
.116	088	1.8	1.7	31,500	15,000 7,600	16,700 4,600	14,200 3,600	10,300	66	24	6	67	148
130	.082	2.5	1.4	34,400	3,900 4,000	5,900	3,400	4,300	69	37	44	87	149
.116	.090	2.0	1.4	27,000	4,200 2,700	4,100 1,500	3,000	3,100	80	22	30	88	150
116	.082	2.0	1.6	14,000	1,600 1,200	2,100 1,100	1,100 900	1,300	78	29	20	91	151
.126	098	2.9	1.7	9,800	1,100	.....	.....	1,100	75	22	41	89	152
.130	.110	2.2	1.6	16,000	2,400 1,900	1,500 1,000	2,600 1,000	1,700	73	15	27	89	153
.128	.104	2.6	1.9	5,300	1,700 1,300	2,400	1,200	1,600	57	19	27	70	154
.160	.116	2.8	2.1	7,300	3,200	.....	.....	3,200	55	28	25	56	155
.124	.110	2.3	2.0	5,200	4,800 1,800	2,500 1,600	1,900	2,500	67	11	13	52	156
204	.112	3.1	1.7	105,000	16,500 5,500	10,600 2,500	9,700 1,500	7,700	74	45	45	93	157
112	.098	2.1	1.6	7,100	2,660	.....	.....	2,600	60	12	24	63	158
.106	.098	1.8	1.5	5,400	2,000 1,100	2,200 800	1,600	1,500	71	7	17	72	159
.128	.102	1.9	1.6	4,700	1,600 500	900 600	600 600	800	54	20	16	83	160
.162	.120	2.6	2.0	5,200	1,400	900	.....	1,200	82	26	23	77	161
.266	.124	4.4	3.1	7,000	4,900 2,800	3,300 2,300	2,100 1,800	2,900	67	53	30	59	162
.698	.170	10.9	4.0	23,800	7,900 5,900	6,400 8,000	4,900	5,500	79	76	63	77	163
518	.162	8.4	3.9	19,800	5,100	.....	.....	5,100	73	69	54	74	164
.500	.152	7.3	3.5	16,800	3,900 5,400 5,600	4,000 4,900	6,300 2,800	4,700	80	70	52	72	165
.390	.162	7.4	4.0	11,200	4,800 2,800	4,100 2,500	3,700 2,700	3,400	68	58	46	70	166

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
167	Nov. 1	Nov. 4, 12:35 AM	16.0	71.4	334	....	....	....	70
168	" 2	" 4, 6:30 AM	14.6	72.2	180	64 47	48 48	54 43	51
169	" 4	" 6, 6:30 AM	12.5	70.8	109	34 29	34 28	31 25	30
170	" 4	" 8, 1:45 AM	12.5	88.6	131	....	....	....	28
171	" 7	" 10, 10:30 AM	11.4	47.7	118	53 39	46 42	47 37	44
172	" 8	" 10, 10:30 AM	10.6	50.1	84	....	....	....	58
173	" 8	" 10, 8:30 PM	10.6	69.5	156	52 47 150	46 46 143	47 33 136	45
174	" 10	" 12, 4:30 PM	15.5	69.5	504	124	124	....	135
175	" 11	" 14, 8:30 PM	16.5	73.6	426	....	....	....	128
176	" 12	" 15, 2:00 AM	19.5	75.0	306	72 67	70 57	68 52	64
177	" 16	" 16, 11:30 PM	27.3	34.9	396	118 106	110 106	106 91	106
178	" 16	" 19, 1:20 AM	27.3	61.2	392	110	....	....	110
179	" 17	" 19, 7:00 AM	26.1	73.5	281	89 68	65 61	72 57	69
180	" 19	" 21, 7:00 AM	21.8	65.9	187	58 41	49 44	45 39	46
181	" 20	" 23, 5:40 AM	19.8	70.5	209	43	....	....	43
182	" 21	" 23, 8:10 PM	17.4	76.4	181	43 45	41 34	42 29	39
183	" 24	" 26, 8:00 AM	19.5	71.5	157	36 34	36 25	32	33
184	" 26	" 28, 2:30 AM	17.4	59.5	101	30 18	30 25	27 16	24
185	" 28	" 29, 12:00 PM	16.0	55.3	98	25 12	18 15	19	18
186	" 30	Dec. 1, 11:00 PM	14.0	54.2	94	29 21	22 14	18	21
187	Dec. 2	Dec. 3, 4:45 PM	12.2	62.9	112	20 31	16 17	18 14	19
188	" 3	" 5, 10:30 PM	11.6	74.6	50	17 15 11	16 13	16 14	14
189	" 6	" 8, 3:25 AM	15.8	54.9	455	150 150	158 150	158 83	141
190	" 8	" 10, 7:50 AM	17.0	66.4	205	88 72 70	76 63	74 74	73
191	" 10	" 12, 11:00 PM	18.2	83.3	247	118 86 62	89 72 59	89 83	82
192	" 13	" 14, 11:00 PM	14.5	69.7	111	55 48	57 42	50	50

Efficiency of the Subsiding Tanks—(Continued).

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				Serial Lot.
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed.			Subsided Water.					Organic Matter.			
River Water.	Subsided Water.	River Water.	Subsided Water.	River Water.	A.	B.	C.	Average.	Suspended Matter.	Nitrogenous.	Carbonaceous.	Bacteria.	
.166	.160	8.1	4.0	15,300	5,100	.....	.....	4,000	79	64	51	74	167
.358	.150	6.7	3.8	14,200	4,300 3,600	3,400 3,400	4,300	3,800	72	58	43	73	168
.308	.136	6.0	3.7	6,900	2,300 2,200	1,700 1,300	2,100 1,500	1,800	72	54	38	74	169
.266	.140	5.7	3.9	6,400	3,100	.....	.....	3,100	79	47	32	52	170
.236	.154	4.9	3.5	21,000	8,700 7,100	11,400 5,100	9,500 5,500	7,900	63	35	29	62	171
.224	.144	5.3	3.9	24,800	9,100	.....	.....	9,100	32	36	26	63	172
.232	.158	5.3	3.6	25,300	11,900 7,700	14,400 5,400	6,300 8,100	9,000	71	32	32	64	173
.552	.324	8.4	5.6	111,000	65,000 30,500	47,000 33,500	36,000 36,900	41,500	73	41	33	63	174
.484	.330	9.7	5.7	126,000	.....	.....	.....	46,000	70	32	41	64	175
.468	.176	6.5	4.1	29,100	25,000 23,400	15,900 17,000	24,500	21,200	79	62	37	27	176
.472	226	8.2	5.9	30,700	27,000 29,000 22,000	25,000 25,200	23,100 22,600	24,800	73	52	28	19	177
424	.208	8.1	5.6	33,900	17,700	....	.....	17,700	72	51	31	48	178
436	.202	8.1	5.0	29,300	13,500 7,000	6,600 7,400	10,900	9,100	75	54	38	69	179
.340	.172	6.9	4.7	14,000	7,400 5,300	6,900 3,400	6,400 4,700	5,700	75	49	32	59	180
.286	.170	6.6	4.4	21,400	8,600	6,100	4,900	6,500	79	41	33	70	181
.318	.120	7.1	4.1	11,200	6,600 5,100	7,000 2,600	5,500 3,100	5,000	78	62	42	55	182
.236	.108	5.1	2.8	11,900	4,100 2,300	3,900	2,200	3,100	79	54	45	74	183
.188	.112	4.0	2.8	8,200	3,900 2,600	5,500 4,200	3,900 3,500	3,900	76	40	30	52	184
.160	.110	3.8	2.8	7,200	3,900 2,800	3,900 2,000	2,600	3.000	82	31	26	58	185
.168	.108	3.7	2.7	8,700	6,700 3,000	5,600 3,000	5,300 3,700	4,600	78	36	27	47	186
.128	.098	3.2	2.4	6,300	4,200 2,900	3,200 2,600	3,400	3,300	83	23	25	48	187
.112	.090	3.2	2.5	7,600	4,400 2,600 2,400	3,800 2,300	2,700 3,900	3,200	72	20	22	58	188
.446	.314	8.0	5.4	144,300	85,000 34,500	141,700 26,700	36,000 55,500	63,200	69	30	33	56	189
.240	.202	4.9	3.4	52,900	49,500 24,500 22,800	25,300 24,300	27,000 23,300	28,100	64	16	31	47	190
.322	.164	5.2	3.5	34,200	38,400 15,500	23,100 14,400	21,000 14,900	21,200	67	49	33	38	191
.184	124	3.3	2.9	24,700	20,200 14,700	14,700 17,700	12,400 15,600	15,900	55	33	12	36	192

Record of the Operation and the

Serial Lot.	Date, 1898. Filled.	Began to Use.	Stage of River. Feet.	Average Period of Subsidence, in Hours, from End of Filling.	Suspended Matter in Parts per Million. River Water.	Subsided Water. A.	B.	C.	Average.
193	Dec. 15	Dec. 17, 7:05 AM	12.3	68.7	37	31 28 26	28 25 28	28 25 23	27
194	" 17	" 20, 12:30 AM	10.8	81.5	31	20 18	17 17	18	18
195	" 20	" 21, 6:00 PM	15.8	65.0	1,130	175 165	175 165	150 114	156
196	" 20	" 24, 4:45 AM	15 8	99.1	927	165	158	....	161
197	" 21	" 25, 1:30 AM	17.5	97.9	295	110 83	83 89	106 98	95
198	" 24	" 27, 1:20 AM	27.0	87.4	311	83 76	68 81	72 72	75
199	" 27	" 29, 4:20 AM	31.9	72 2	374	91 78	81 76	78 76	80
200	" 29	" 31, 9:30 AM	28.5	69.0	170	51 51 52	51 51	46 46	56
201	" 31	Jan. 3, 3:00 AM	23.7	59.5	301	98	....	....	98
202	1899. Jan. 3	1899. Jan. 3, 1:22 PM	19.0	3.0	80	....	....	....	75
203	" 5	" 5, 8:00 AM	20.5	3.0	256	....	....	....	243
204	" 5	" 6, 11:10 PM	20.5	58.2	434	118 124 114	130 114	136 124	123
205	" 7	" 9, 3:30 AM	24.4	54.8	159	57 53	51	54	54
206	" 8	" 10, 3:10 PM	33.6	62.0	681	136 124	130 114	130 102	122
207	" 10	" 11, 3:45 PM	41.4	57.2	383	145 122	140	145	138
208	" 11	" 14, 5:15 AM	43.2	106.1	419	124 91 91	106 91 91	86 76 91	94
209	" 14	" 17, 5:30 AM	38.0	98.2	863	150 185 158	150 165 150	165 142 150	157
210	" 17	" 20, 5:10 AM	41.0	102.8	500	150 150 136	118 124 130	128 124 124	132
211	" 20	" 23, 5:15 AM	39.7	79.8	418	124	106	106	112
212	" 23	" 24, 7:00 AM	30.6	29.6	174	78 68	70	65	70
Averages*....	.....		....	61.8	231	....	....	....	62

*These averages do not include lots Nos. 202 and 203.

Efficiency of the Subsiding Tanks—(Concluded).

Total Organic Matter. Parts per Million.				Bacteria per Cubic Centimeter.					Average Efficiency of Subsiding Tank in Percentage Removal of				Serial Lot.
Nitrogen as Albuminoid Ammonia.		Oxygen Consumed		River Water.	Subsided Water.				Suspended Matter.	Organic Matter.		Bacteria.	
River Water.	Subsided Water.	River Water.	Subsided Water.		A.	B.	C.	Average.		Nitrogenous.	Carbonaceous.		
.122	.114	2.5	2.3	14,600	16,000 10,700 18,300	14,500 13,000 4,800	14,300 10,500	12,800	27	7	8	12	193
120	.106	2.7	2.0	13,400	19,800 6,200	16,600 6,500	10,300	11,900	42	12	26	12	194
.868	.350	13.3	5.4	51,300	55,900 52,500	54,000 36,000	58,500	51,400	86	60	59	0	195
.846	.294	12.6	5.2	46,800	100,000	96,000	.....	98,000	83	65	59	—109	196
.372	.260	6.9	4.6	89,000	37,500 27,000	26,200 21,000	29,500 27,700	28,100	68	30	33	68	197
348	.180	6.3	3.3	34,200	28,500 15,300	17,000 14,500	17,000 15,700	18,000	76	48	48	47	198
.426	.180	7.3	3.9	37,500	33,500 22,100 14,900	20,800 21,200	29,600 16,700	22,700	79	58	47	40	199
.244	.138	5.4	3.1	25,800	12,300 8,500 6,900	9,800 7,800 11,700	8,700 9,000	9,300	67	48	43	65	200
548	.214	7.0	3.8	31,000	21,100	.....	.....	21,100	67	61	46	32	201
.224	.198	3.7	3.7	16,500	19,300 13,800	20,500 13,700	17,200	16,900	6	12	0	—2	202
.330	.326	5.8.	5.3	27,600	26,100 25,300	25,500 13,500	29,800	24,000	5	1	9	13	203
.526	.268	8.0	4.8	42,200	25,900 32,000 26,000	24,000 27,000	19,900 19,300	24,900	72	49	40	41	204
.228	.152	4.9	3.1	14,600	19,500 12,500	15,800	13,700	15,400	66	34	37	—5	205
.546	.284	11.4	4.6	33,800	18,200 16,400	21,500	17,000	18,800	82	48	60	46	206
.386	.238	8.6	4.9	20,900	15,600 15,000 9,600	16,700 12,300	13,700 11,200	13,500	64	38	43	35	207
.394	.208	8.7	4.3	22,300	12,100 14,800 12,400	11,500 12,600 15,600	17,300 13,500 10,900	13,400	78	47	51	40	208
.830	.330	11.8	5.6	31,800	28,500 19,800 14,500	25,500 18,500 15,200	17,600 16,900	19,600	82	60	53	38	209
.484	.292	9.6	5.9	38,400	22,000 22,100 11,100	19,500 19,500 13,500	15,000 12,400 11,900	16,300	74	40	39	58	210
:488	.238	7.7	5.2	32,500	19,400	11,500	14,100	15,000	73	51	32	54	211
.254	.182	5.1	3.5	18,900	8,400 5,800	8,500 2,500	6,300	6,300	60	28	31	67	212
.275	.150	5.2	3.0	16,300	.....	.....	.....	6,200	73	45	42	62	.....

EFFECT ON THE TEMPERATURE OF WATER OF STORAGE FOR TWO TO THREE DAYS.

Owing to the effect of direct sunlight upon portions of the steel tanks and the radiation effects from the sides of the tanks, conditions which would not arise in practice, it seems impracticable to draw any specific conclusions from the effects of storage for from two to three days in the steel tanks used in these experiments. The average of the temperatures of the river water and the subsided water were almost exactly the same, but differences from 3 to 5 degrees Fahrenheit occasionally occurred, the subsided water having been higher and lower by that amount at different times during both the warm and cold weather. In large basins it seems reasonable to believe that fully as great differences as this might be found, and that they would be far more consistent and constant with reference to increases and decreases from the initial temperature.

EFEECT OF TEMPERATURE OF WATER ON SUBSIDENCE.

In the operation of the subsiding basins it was not found practicable to obtain data which would throw light upon this question. Laboratory experiments, however, indicated that a difference of temperature as small as 3 degrees Fahrenheit would make a sufficient difference in the density to set up convection currents, when the temperature of the water admitted differed by that amount from the temperature of the water in the vessel. Judging from this fact, and from the probable range in temperature of the water in large basins, it seems probable that there would be a considerable tendency at times for currents to be set up in filling a basin already partly full of water, due to differences in the density of the water in the basin and of that being admitted.

DISPOSAL OF ACCUMULATED SEDIMENT AT THE BOTTOM OF THE TANKS.

From March 28 to April 15 the tanks were not drained or cleaned. Beginning on April 15, the tanks were regularly drained and usually cleaned. During this period the accumulated sediment formed a thin sludge from 0.25 to 1.5 inches thick in the level bottom of the tanks. This sludge was readily flushed out with a stream of water from a hose. In order to study the effect of the accumulation and storage of sediment upon the character of the layer, tank B was not cleaned from August 6 to September 9; tank C was not cleaned from August 5 to September 29; and tank D was left from August 3 to October 5. Tank B was again cleaned on September 24, tank C was cleaned on December 29, and tank D was cleaned on January 4. The first of these periods will be considered in detail, but the presence of ice prevented the collection of data of value on the accumulations of sediment during the winter weather.

From August 6 to September 9 tank B was filled seven times, and the average suspended matters in the river water were 408 parts per million, and the average removal was 71 per cent. The total amount of water put in this tank was 856,000 gallons; and, using the above figures, the amount of suspended matter removed, if estimated as dry clay, at 110 pounds per cubic foot would represent a layer on the bottom of the tank 0.46 inch thick. The actual layer found was 1.75 inches thick, of such a consistency that it could be flushed and swept out, though with difficulty.

From September 9 to September 24 tank B was filled four times, with a total of 492,000 gallons of water. The average amount of suspended matter in the river water was 117 parts,

from which the removal averaged 80 per cent. This corresponds to a layer less than 0.1 inch thick, and the actual layer was a thin sludge 0.5 inch thick, which was readily flushed out with a stream from a hose.

In neither of the above cases in tank B was there any marked decomposition of the sediment, though on September 9 there was a distinctly foul and disagreeable odor.

Tank C was not cleaned from August 5 to September 29, during which time it was filled eleven times, with a total of 1,377,000 gallons of water. The suspended matter in the river water averaged 331 parts and the average removal was 87 per cent. This corresponds to a layer of clay 0.72 inch thick. When this tank was cleaned there was found a semi-solidified layer averaging 2.75 inches thick, and of a consistency which could be readily shoveled, but was too consistent to be flushed from the flat bottom of the tank to the small sewer connection with a stream of water from a hose. The lower portion of this layer was very dark in color, and the odor was very foul.

Tank C was again cleaned on December 29. During the period from September 29 to December 29 the tank was filled twenty-one times, with a total of 2,582,000 gallons of water. The average suspended matter in the river water was 227 parts and the average removal was 71 per cent. This corresponds to a layer 1.92 inches thick, and there was found a very consistent layer 3 inches thick. This layer was too consistent to flush from the level surface with a stream from a hose, but was shoveled to the sewer pipe, where it was flushed into the sewer after having been broken up into small lumps. On the underside the sediment layer was quite green, but there was no appreciable odor.

Tank D was not cleaned from August 3 to October 5, when

a semi-solidified layer 1.75 inches thick was removed. This layer was very dark in color, and was sufficiently consistent to be removed with a shovel, but was too sticky to be flushed out with a stream of water from a hose through the small outlet opening. During this period the tank was filled fourteen times, using a total of 1,734,000 gallons of water. From this water an average of 78 per cent of the suspended matters, which averaged 326 parts per million, were removed, corresponding to a layer of clay 0.80 inch thick.

From the records presented above it may be concluded that sediment deposited in this manner forms a layer whose consistency gradually increases from a very fluid state at first to a thick fluid in from two to three weeks. From this time on it becomes more and more consistent, probably on account of two actions. The first and less important of these is the compacting of the layer due to its own accumulation. The main reason seems to lie in the products resultant from the decomposition of the organic matter, or rather incidental thereto. In a general way, it is probable that the process of decomposition of the organic matter, being one which requires oxygen, results after the oxygen present in the water of the sediment layer has been exhausted, and after a reduction of the oxygen present in the mineral compounds, such as the sulphates and nitrates, and the reduction of ferric to ferrous iron. This action begins, as judged from the above data, in less than a month. In fact, there is reason to believe that in one or two months this action progresses to a sufficient degree to liberate considerable amounts of hydrogen sulphide. The next step seems to be the reaction of the sulphide compounds with the ferrous iron, resulting in the formation of ferrous sulphide, a black gelatinous precipitate which forms the cementing material which transforms the thick fluid to a semi-solidified

mass of a tenacious character more or less resembling rubber. Apparently this action is not very marked in the first month. though it begins, but by the end of the second month it is fairly complete, and has reduced the sediment layer to a condition where shoveling or violent-water jet action is necessary to cause its removal under the condition which obtained in these flat-bottomed tanks with one small outlet at the bottom on one side.

In practice, where the side and bottom of the basin would be sloped, and where a channel would be provided for the removal of the sediment by a large stream of water from a hose, it is clear that the accumulated sediment during several months of operation could be removed without difficulty. How long, from an economical standpoint, it would be advisable to allow the sediment to accumulate before it was removed, is a matter which can not be definitely settled from present evidence. From the experience so far as known in cleaning the Covington reservoirs, it appears that the removal of sediment need not economically take place for many months, and possibly the intervals between cleaning could to advantage be a year or more.

THE REMOVAL OF DISSOLVED CONSTITUENTS OF THE RIVER WATER BY PLAIN SUBSIDENCE.

The results of quite an extended series of special analytical comparisons of the river water before and after subsidence showed that there was practically no effect produced by subsidence upon the dissolved constituents of the water, namely: Nitrogen as dissolved albuminoid ammonia, as free ammonia, as nitrites, and as nitrate; chlorine; sulphuric acid; incrusting constituents; alkalinity; dissolved residue on evaporation; carbonic acid; and dissolved oxygen.

In fact, there was no instance in which the difference in the dissolved constituents of the water before and after subsidence was in excess of that capable of complete explanation by discrepancies in sampling and in analysis.

COMPARISON OF TURBIDITY OF WATER AT DIFFERENT DEPTHS IN THE SUBSIDING TANKS AFTER SUBSIDENCE FOR TWO TO THREE DAYS.

Concerning the relative degrees of clarification of the water at different depths in the subsiding tanks, it may be said that except for a thin stratum at the top and another at the bottom of the tank there was very little difference found in the grades of water examined with reference to this point.

The upper stratum of water, somewhat less than 6 inches thick, and the lowest 6 inches of water were unusually clear and unusually turbid, respectively; but between these strata the water was found in all cases to be uniform, practically speaking, though showing a slight tendency to increase toward the bottom in the amount of suspended matters. This is clearly seen from the following table, where averages of several observations are presented:

Suspended Matter in Ohio River Water after Three Days' Subsidence.

Distance from Surface.	Suspended Matter.	Percentage Removal.
0.25 feet.	137 parts per million.	78.8
3.00 "	190 " "	70.3
8.00 "	195 " "	69.5
13.00 "	197 " "	69.2
23.00 "	206 " "	67.8
28.00 "	200 " "	68.7
30.00 "	215 " "	66.4
31.00 "	200 " "	68.7
32.00 "	206 " "	67.8
33.75 "	641 " "	00.0

In order to establish more clearly the probable loss in efficiency of these tanks where the water was drawn from three fixed points, starting in each case about 10 feet below the surface of the water and drawing down the entire stratum above the outlet, as compared with surface drawing, special samples were collected from the upper stratum of water (surface to 6 inches below), and from the subsided water when first starting to draw from 10 feet below the surface. These sets of samples, thirteen in number, were taken on nine different lots of water during the August rise, and probably represent the conditions during fairly muddy water in a satisfactory manner. The average of these samples gave the following results:

Average Parts per Million of Suspended Matter.

Upper six inches, 98; ten feet below surface, 113.

These data show that there was 15 per cent more suspended matter in the water 10 feet below the surface than in the upper 6 inches. The suspended matter in the water represented by the above averages ranged from 277 to 867, and averaged 472 parts per million. This makes the percentage removals represented by the averages given above 79 and 76, respectively. In the table given above, the increase is 43 per cent from the upper 3 inches to 10 feet below the surface.

These figures probably represent fairly well the conditions which would obtain in practice in large basins during rises in the river, and indicate that it would be of material advantage at times of muddy water to draw the water from the upper 6 inches; but that if it was not found practicable to locate the outlet nearer than 1 foot from the surface, no marked loss in efficiency will be found if the outlet was located several feet below the surface.

AVERAGE REMOVAL OF SUSPENDED MATTER IN THREE DAYS OF PLAIN SUBSIDENCE.

At the outset of these investigations it was decided to adopt 72 hours (three days) as the normal average period of subsidence, and the operation was arranged to obtain as nearly this period as practicable. In all, 38 lots of water were used during these experiments, on which the period of subsidence was within 4 hours of the prescribed; or, in other words, between 68 and 76 hours.

The average period of subsidence on these 38 lots was 71.2 hours, and the average removal of suspended matter was 72 per cent. The minimum removal was 54 per cent on a clear river water (35 parts per million) and the maximum 91 per cent, also on a fairly clear water (68 parts).

A more complete study can be made, however, from the samples collected after from 68 to 76 hours' subsidence, irrespective of the actual average period of subsidence for the lot. The averages obtained in this way are presented in the following table. These figures show the removal for different lots of water and also the grand average for all lots:

Suspended Matter in River Water in Parts per Million.

Range.	Original.	After 72 Hours' Plain Subsidence.	Percentage Removal.
1-50	38	12	68
51-100	73	19	74
101-250	166	48	71
251-500	330	93	72
501-1000	665	184	72
1,000 and over	1,235	222	82

Taking an average of all observations, a removal of 73 per cent is obtained, which it is believed is a very fair figure.

Comparing this with the total average of all observations on the operation of these tanks (see preceding table of complete data), it is to be noted that the average given here for 72 hours corresponds quite closely to the figure for the average period of 61.8 hours. For the latter period the actual averages of the suspended matter in the water before and after subsidence showed a removal of 73 per cent, while the averages of the individual (lot) removals make this figure 71 per cent.

The evidence in regard to the removal of organic matter, bacteria, and dissolved constituents is presented in subsequent sections.

During stages of high water the suspended matter is usually to a large percentage quite coarse and settles out readily. On this account the percentage removal at these times would normally be considerably above the average. In the table given above, the average removal when the suspended matter in the river water was over 1,000 parts was 82 per cent in 72 hours, and it seems quite probable that, with the muddiest waters of the winter and spring freshets, over 90 per cent removal might be expected.

Taking every thing into consideration, the evidence indicates clearly that on an average substantially 75 per cent of the suspended matter can be removed from the local river water by plain subsidence for three days.

ON THE RELATIVE EFFECTS OF SUBSIDENCE FOR DIFFERENT PERIODS.

In the course of operation of the subsiding tanks the periods of subsidence were, for reasons explained above, varied from time to time. These variations furnished results which allow of comparison of the effects of different periods of subsidence beyond 24 hours. In the following table are

presented averages of all results obtained in this manner, arranged to show the relative values of subsidence for different periods with different grades of water.

Increased Removal of Suspended Matter by Plain Subsidence for Successive Days beyond the First Day.

Period.	Suspended Matter in River Water in Parts per Million.							
	1–100.		101–250.		251–500.		Above 500.	
	Parts Removed.	Per Cent Removed.	Parts Removed.	Per Cent Removed.	Parts Removed.	Per Cent Removed.	Parts Removed.	Per Cent Removed.
24–48 hours	8	12	10	6	17	5	..	..
48–72 "	3	4	7	4	14	5	13	2
72–96 "	4	6	8	4	13	4	24	4

Average Increased Removal of Suspended Matter by Plain Subsidence for Successive Days beyond the First Day.

Period.	Additional Removal.	
	Parts per Million.	Percentage.
24–48 hours	10	6
48–72 "	9	5
72–96 "	10	4

The above results are so uniform as to make the following deductions very plain:

1. The increased removal for additional periods of 24 hours beyond the first day is higher in percentage for waters low in suspended matters, but the actual removal is higher with muddier waters. The range is not, however, sufficiently great to

be of practical significance, and is closely represented by the following average figures:

Range of Suspended Matter in River Water.	Average Additional Removal per Day for the Three Days after the First Day.	
Parts per Million.	Parts per Million.	Percentage.
1–100	5	7
101–250	8	5
251–500	15	5
500 and over	18	3

2. The average increased removal for all classes of this river water is 6 per cent for the second 24 hours, 5 per cent for the third, and 4 per cent for the fourth day, in percentages of the total suspended matter originally present.

AVERAGE REMOVAL OF SUSPENDED MATTER BY PLAIN SUBSIDENCE FOR DIFFERENT PERIODS.

Using the figures presented in the two preceding sections, and the actual observations during the operation of the subsiding tanks, the relative range in removal of suspended matters in different periods of subsidence is estimated in the following table:

Period of Subsidence.	Percentage Removal of Suspended Matter.		
	Maximum.	Minimum.	Average.
24 hours	85	25	62
48 "	90	30	68
72 "	95	40	72
96 "	95	45	76

Owing to the fact that the data from the operation of the subsiding tanks did not include the period of winter freshets,

it is probable that the above percentages are slightly too low for annual averages. Thus the 72 per cent recorded for 72 hours of subsidence seems to be less correct for an annual average than 75 per cent as previously stated.

THE REMOVAL OF ORGANIC MATTER BY PLAIN SUBSIDENCE.

Those organic particles which are suspended in a water naturally tend to subside, and their removal by this means seems to vary with their character and amount, and with the period of subsidence. Examination of the records of operation of the subsiding tanks shows that the maximum, minimum, and average removals of nitrogen as albuminoid ammonia were 76, 5, and 45 per cent, respectively; while the corresponding figures for oxygen consumed were 64, 6, and 42, respectively. As there was no appreciable change in the amount of the dissolved constituents, the amounts removed were wholly in suspension; but the percentage removal is determined as a percentage of the total. Concerning the suspended organic matter, as indicated by the nitrogen as albuminoid ammonia, the percentage of removal was found to be 68 on an average.

THE REMOVAL OF BACTERIA BY PLAIN SUBSIDENCE.

In the operation of the subsiding tanks, with periods of subsidence ranging from one to over four days, it was found that for most classes of water a large percentage of the bacteria present in the river water was removed by subsidence in the first day. At times there was a continual decrease in the numbers of bacteria during the use of the lot, due to subsidence during drawing, but as a rule this did not amount to any very large percentage.

The lowest average removal during these investigations

in the probable absence of growths was 19 per cent on lot No. 177, with an average of 34.9 hours of subsidence. At the beginning of the use of this lot (10 hours' subsidence) the removal was 12 per cent, and at the end (after 60 hours' subsidence) the removal was 28 per cent.

The maximum average removal was 97 per cent, which was obtained on lots Nos. 76, 79, and 80, with 82.1, 67.7, and 82 hours of subsidence, respectively. The removal on lot No. 125, which had the longest period of subsidence (136.4 hours), was only 75 per cent.

The average removal on all observations at 72 hours was 75 per cent, but for the entire investigations, with an average of 61.8 hours' subsidence, the average removal was 62 per cent.

In regard to the growth of bacteria within the subsiding tanks, there did not seem to be any evidence of such growth during the hottest part of the summer; but in November there developed a tendency which became very clearly defined in December (lots Nos. 193 to 196, inclusive) for growths of bacteria to occur in the water during subsidence. These growths were confined almost exclusively to one species of common water bacteria, one of the harmless fluorescent group. At first it was thought that this growth was due to the accumulation of sediment in the bottom of the subsiding tanks. It was proven, however, that if this was a factor at all it was a small one, because similar growths occurred in the same river water subsided in clean wooden tanks.

So far as our knowledge goes, these growths were due to peculiar and unusual conditions in the river water, and are not to be regarded seriously, as these growths at rare intervals are doubtless confined to perfectly harmless kinds of bacteria.

CHAPTER IV.

Description of the Operation of the Original English Filters receiving Plain Subsided Water, and a Summary of the Principal Results accomplished Therewith.

The construction of the fifteen original filters of the English type was completed on March 5, 1898. On March 5 to 7 they were filled with subsided water. The coarse sand filters, Nos. 3, 6, 9, 12, and 15, were filled first from the top at a rate of about two million gallons per acre daily. From these filters the remaining ones were filled from below through the "side-filling" pipes at the above stated rate.

Owing to the fact that the subsiding tanks were not in readiness to deliver subsided water regularly to the filters until March 28, it was not until this date that the filters were placed in regular and official operation.

During the three weeks March 7 to 28 the filters remained filled with subsided water, with practically no disturbances except that they were started for about one hour on March 26 to test the meters. The subsided water as applied to the filters had a temperature of about 50° Fahrenheit, and contained about 75 parts per million of suspended matter. From March 7 to 28 the records of the local Weather Bureau show that the maximum, minimum, and mean temperature of the air were 74°, 34°, and 55° Fahrenheit, respectively.

Just before starting the filters on March 28, samples of water above the sand in several filters were collected, and analyses showed that the water on an average contained 30 parts per million of suspended matter and 1,200 bacteria per cubic centimeter.

DESCRIPTION OF THE NORMAL OPERATION OF THE ORIGINAL ENGLISH FILTERS.

Among the essential objects of these investigations were comparisons of the efficiency and economy of coarse, medium, and fine sands obtained from the river near the waterworks; of the thickness of sand layers of 1, 3, and 5 feet, representing the range of modern practice; and of rates of filtration of 1.5, 2.6, and 4.0 million gallons per acre daily. Of these rates the first two represent the range ordinarily obtained for municipal filters, while the highest one was found at the Lawrence Experiment Station to be satisfactory in the treatment of the Merrimack River water.

Arrangements were made whereby data upon these points were secured from the operation of the fifteen original filters constructed as described in Chapter II. Excepting in the rate of filtration, these filters in their principal phases were operated in a manner substantially common to all.

The general procedure of regular operation of these filters is herewith presented, concluding with a tabular summary of the leading features of the construction and the operation of the respective filters. Following this section is a more detailed account of the most important considerations in connection with the scraping of the filters, and with reference to the retention of the fine clay particles of the applied water at and near the surface of the sand layer.

Continuous Plan.—All of the filters were operated on the continuous plan, and the water stood about 4.2 feet above the original sand surface in each filter, except at times of scraping. The valves at the filter on both the inlet pipe and the outlet pipe were normally kept wide open. As was stated in Chapter II, a practically constant level of the water in the filters was maintained automatically by the aid of the regulating tank.

Regulation of Rate.—By means of the valve at the meter, which in each case was placed at the end of the outlet pipe extending to the meter room beneath the main platform, the rate of filtration was regulated as required. The rate was observed three times daily, and it was changed when it was found to be different from the normal rate by more than 5 per cent.

Loss of Head.—In about fifteen minutes after the adjustment of the rate of filtration, observations were taken upon the loss of head of the water as it flowed through the respective filters.

Collection of Samples.—Samples of the effluent of each filter and of the subsided water as it was applied to the filters were collected three times daily for bacterial analyses, and once daily for chemical analysis and for inspection of the clearness of the effluent.

Head Utilized.—The above features constituted the normal operation of the filters up to the time of scraping. Loss of head observations usually served as the guide to the decision as to when the filters should be scraped. In the case of each filter the first scraping was made when the loss of head reached the maximum available head, about 13 feet. As the horizontal section of greatest frictional resistance in an English filter is at the surface of the sand layer, only about 4 feet of the available head was positive, the remaining 9 feet being negative. It was found that the negative head (suction) reduced the pressure on

the water within the sand layer to a point where the nearly saturated water gave off air which accumulated in the interstices of the sand layer. These accumulations of air, as will be brought out fully beyond, increased the frictional resistance of the filters so rapidly that only a comparatively small quantity of water was filtered after the loss of head equaled the positive head or depth of water above the sand.

Beginning in May, after the first scraping of each filter, it became the normal custom to scrape the filters when the loss of head reached 4 feet, practically equal to the positive head. In a number of cases the filters were scraped when the loss of head was much less than 4 feet. During the very turbid water in the river at the time of the August rise, the filters were scraped when the loss of head reached only 2 feet, in order to aid in lessening the deep penetration of the clay in the subsided water down into the sand layer. The several filters were also scraped at times, independent of the total loss of head, when it was apparent that disturbances had occurred at the surface of the sand layer. The disturbances were due to animal life, as described beyond, and produced to a greater or less degree the inadmissible result of unequal rates of filtration through the sand layer.

Scraping.—When it was decided to scrape a filter the valve on the inlet pipe at the filter was closed, and the water above the sand was removed by filtration at the normal rate. Owing to the steadily decreasing head, it was necessary at such times to adjust the rate at more frequent intervals than ordinarily. The valve on the outlet pipe was closed when the water level in the sand had reached at least 1.0 foot below the surface, though as a rule the filter was drained nearly dry. After the upper portion of the sand layer became fairly dry, usually at two to three hours after the water had disappeared from the

surface, some thin boards were placed upon the sand layer, to prevent the boot-heels of the workmen from making holes in the sand. The workmen with square-edged moulders' shovels then scraped off the surface of sand to the desired depth. Owing to some unevenness in the surface of the sand during the first few months of operation, it was the custom to level the surface somewhat.

Depth of Scraping.—Concerning the thickness of the layer of sand which was removed, the procedure was modified in the course of the investigations in accordance with the evidence obtained. This will be described more fully just beyond. In general terms it may be stated that the scrapings up to about August 1 removed practically all of the sand which was distinctly discolored; but after this date the scrapings were not thicker than about one inch, independent of the distance to which the discolored sand extended.

Filling from Below.—On completing the scraping of the sand surface, the filters were uniformly filled from below with filtered water at the same rate at which the water passed through the particular filter when in normal operation. Up to June filtered water was taken from an adjoining filter through the "side-filling" pipes. This was not thoroughly satisfactory, owing to difficulties in controlling the rate of flow. After this date the filtered water was applied below through the outlet pipe, which was disconnected just above the meter, and to which was attached a hose receiving filtered water through another meter, either from one of the other filters operated at the same rate, or from the wash water tank used in connection with filter No. 20. With proper attention the filters could be safely filled in this manner from below, thus driving the air from the pores of the sand layer and avoiding

disturbances in the sand which would result in channels of lessened resistance.

The filtered water applied below was allowed to rise until it covered the inlet pipe, about 1.5 inches above the original surface of the sand layer. Then the supply of filtered water was shut off and the valve on the inlet pipe was opened very slightly at first in order to fill the compartment above the sand to its normal depth with subsided water, without disturbing the surface of the sand.

Resumption of Filtration.—Normally the outlet was opened and filtration at the prescribed rate was begun as soon as the subsided water above the sand had reached its usual level. At the time of the August rise, when the subsided water contained comparatively large quantities of very fine clay in suspension, the water above the sand was allowed to settle over night before opening the outlet, and the rate of filtration for the first day was reduced to about 60 per cent of the normal. Directly following a scraping of a filter a special series of samples of the effluent was taken uniformly, in order to learn the bacterial efficiency of the filters following this part of the operations.

Discontinuance of Filters.—The data, which were obtained upon the efficiency and cost of clarification and of purification of the Ohio River water after plain subsidence by the English type of filters, are the results of the operation of the fifteen experimental filters according to the foregoing methods. In studying these data, as they appear in subsequent portions of this report, it will be seen that only one of the filters was continued in operation until the close of the investigations. The explanation of the discontinuance during the work of fourteen of the orginal experimental filters of the English type was the gradual elimination of the less efficient and less practicable filters, in order, first, to provide under the existing

conditions a full period of three days for the plain subsidence of the water applied to the filters; and, second, to obtain a sufficient quantity of plain subsided water for the operation of the new filters, which the current data during the progress of the work indicated to be necessary in order to bring the problem in hand to a logical and practicable conclusion.

Initial Data.—In the following table there are recorded, as a matter of convenience, the principal features wherein the several filters differed from each other in construction and operation. The constant features of construction of the filters are fully recorded in Chapter II, and the constant features in their operation are given in the foregoing pages; but for ease in reference the constants are repeated at this point:

Tabular Summary of the Leading Features in the Construction and Operation of the Original English Filters.*

Number of Filters.	Filtering Materials.					Rate of Filtration.			Date of Discontinuance. 1898.
	Kind of Sand.	Effective Size in m.m.	Uniformity Coefficient.	Thickness, Feet. Original.	Thickness, Feet. Final.	Million Gallons per Acre Daily.	Gallons per Square Foot per Hour.	Vertical Velocity in m.m. per Hour.	
1	Fine	0.21	1.6	1.0	0.45	2.6	2.50	101.4	Aug. 10
2	Medium...	0.28	1.6	1.0	0.40	2.6	2.50	101.4	Aug. 8
3	Coarse	0.34	2.0	1.0	0.80	2.6	2.50	101.4	June 3
4	Fine	0.20	1.6	3.0	1.60	4.0	3.84	156.0	Sept. 24
5	Medium...	0.28	1.6	3.0	1.90	4.0	3.84	156.0	Aug. 23
6	Coarse	0.34	1.9	3.0	2.50	4.0	3.84	156.0	June 3
7	Fine	0.20	1.6	3.0	2.00	2.6	2.50	101.4	Sept. 24
8	Medium. .	0.28	1.5	3.0	1.95	2.6	2.50	101.4	Aug. 23
9	Coarse	0.34	1.9	3.0	2.50	2.6	2.50	101.4	June 3
10	Fine	0.21	1.6	3.0	2.45	1.5	1.44	58.5	Aug. 1
11	Medium...	0.28	1.5	3.0	2.50	1.5	1.44	58.5	Aug. 1
12	Coarse	0.35	1.9	3.0	2.40	1.5	1.44	58.5	June 3
13	Fine	0.27	1.3	5.0	3.50	2.6	2.50	101.4	†Jan. 25
14	Medium...	0.27	1.6	5.0	3.90	2.6	2.50	101.4	Sept. 14
15	Coarse	0.34	1.9	5.0	4.35	2.6	2.50	101.4	June 3

†1899.

*Constants: In addition to the above the following constants are to be considered:

(*a*) All filters were completed on March 5, 1898, and were placed in operation on March 28, 1898.

(*b*) All filters were 11.78 feet in diameter, having an area of 1-400 acre.

(*c*) All filters had a 4-inch layer of graded gravel at the bottom to serve as underdrains and a supporting layer for the sand.

(*d*) All filters had the bottom of the inlet pipe located about 1.5 inches above the level of the original sand surface.

(*e*) All filters carried a column of water of 4.2 feet in depth above the sand, measured from the original surface, and which increased as the thickness of the sand layer decreased.

(*f*) All filters had a total available head of about 13 feet.

CHARACTERISTIC FEATURES WITH REFERENCE TO SCRAPING THE SURFACE OF, AND THE RETENTION OF APPLIED CLAY BY, THE SAND LAYER OF ENGLISH FILTERS, OPERATING UPON OHIO RIVER WATER WHICH WAS SUBSIDED FOR TWO TO THREE DAYS.

One of the most important portions of the process of purification of water by filters of the English type is the scraping of the surface of the sand layer, to relieve the clogging due to surface accumulations of matters removed from the water, and the factors associated therewith. While this is true in a large measure in the case of all waters, both from the qualitative and quantitative point of view, it is true to an unusual degree in the case of the Ohio River water at Cincinnati. The reason for this lies in the inherent natural character of the local water, which differs specifically from most if not all of those waters where the English type of filtration has been found to be applicable to a satisfactory degree.

A thorough description of the operation of the English filters in the purification of the Ohio River water at this point necessitates, therefore, a careful and detailed account of this part of the process. In order to show in a comprehensive manner the scope of the subject, a list of the topics treated in this section is presented at the outset, as follows:

I. The comparative absence from the local water of organic matter such as serves readily to form gelatinous films around grains of sand.

II. The presence in the water more or less regularly of large quantities of very fine particles of clay.

III. The imperfect formation of a gelatinous surface coating (Schmutzdecke) upon the top of the sand layer.

IV. The deep penetration of the fine clay particles from the applied water into the sand layer and its influence upon the depth of scraping.

V. The impracticability of allowing loosened portions of the sand layer at the top (loosened to increase the porosity or to level the surface) to remain in the filter.

VI. The presence in this water almost uniformly of sufficient air to preclude the use of negative heads—that is, acting heads in excess of the depth of water above the sand surface.

VII. The disturbances in an irregular manner of the upper portions of the sand layer due to various forms of animal life naturally contained in this water.

VIII. The imperativeness of guarding against the formation of vertical channels in the sand layer and disturbances of the surface when filling the filters, after draining, to scrape them.

IX. The inadvisability, from the standpoint of the quality of the effluent, of allowing unpurified water to reach the lower portion of a filter, and the consequent necessity of using filtered water for filling filters from below after scraping.

X. Efforts to retain the suspended matters at and near the surface of the sand layer when the applied water is very turbid, by the use of the following procedures:

A. Scraping the filter when the loss of head reaches about one half of the available positive head, or 2 feet.

B. Allowing the turbid water with which the filter above the sand is filled after scraping to settle for 12 to 24 hours, with the view of forming more or less of a sediment layer upon the surface of the sand.

C. Reducing the rate upon the resumption of filtration after scraping to approximately 60 per cent of the normal for 12 to 24 hours.

We shall relate our experience upon the several points in turn.

I. *Comparative Absence in the Ohio River Water of Organic Matter adapted to the Formation of Gelatinous Films upon the Sand Grains.*

In the investigations into the purification of the Merrimack River water at Lawrence by the English type of filtration, it was found that, in general terms, the organic matter in suspension (estimated on an average at about 20 per cent of the total organic matter) was so large in size, when compared with the interstices of the sand layer, that the suspended particles for the most part were retained at and near the surface of the sand. Some of the smaller particles of suspended organic matter passed farther down into the sand layer; and of the dissolved organic matter a portion of it united with certain constituents of the sand and formed around the grains films of a more or less gelatinous nature. The result of these actions by the suspended and dissolved organic matters was under normal conditions to furnish the sand grains with gelatinous

films or coatings, which decreased in thickness from the top of the sand layer downward, and which were most typical at the immediate surface. For the rates of filtration which were employed for that water, it is believed that these gelatinous coatings gave to the sand layer a retentive capacity that materially increased the efficiency of the filter, and provided a factor which at more rapid rates of filtration it is necessary to secure by artificial means.

Proof that these coatings produced by organic matter were of well-defined aid in connection with the qualitative efficiency of those filters was obtained from the abnormally low bacterial efficiency of new filters, even when the immediate surface was clogged so as to be almost water-tight; from the normal bacterial efficiency of old filters when the upper inch of the sand layer was removed; and from the fact that a filter receiving water from the Merrimack River attained normal efficiency far more quickly than a duplicate filter receiving the same water after primary filtration had removed the organic matter in question.

Turning from the Merrimack River water, which from personal experience has been taken as illustrative of the type of water for the purification of which the English type of filtration is peculiarly applicable, to the Ohio River water at Cincinnati, there is found a different condition of affairs with reference to organic matter. So far as the amount of total organic matter is concerned, the Ohio River water rarely if ever contains less than the Merrimack River water, and at times of freshets the amount in the former water far exceeds that in the latter. But with regard to the character of the organic matter it is found that in the Ohio River water the matters capable of forming gelatinous films around sand grains are quite small in amount, comparatively speaking, and this

absence is most noticeable at times of freshets, when the work for the filters to do is greatest.

In consequence of the greater stability of the main bulk of the organic matter in the Ohio River water, proven decisively by the comparative absence of well-marked signs of nitrification by filtration under favorable conditions of practice, English filters operating upon the local water are handicapped to a substantial degree by having to work without the full assistance of well-developed gelatinous coatings for the sand grains.

In explaining this difference in the organic matter in the water of the two rivers, there is no clear reason to believe that on the watershed of the Ohio River there is lacking organic matter such as is present in the other case. But in the Ohio River water there are present almost uniformly sand, silt, and clay to a degree which is practically unknown in the Merrimack River water. If those organic matters forming gelatinous coatings around sand grains are removed from water by its passage through a sand layer, there is good reason to believe that they are also removed to a considerable degree by the passage of sand, silt, and clay through water. The latter movement continuously takes place in the Ohio River during the greater part of the year. From the results of analyses of the materials deposited in the river, it seems quite clear that in the manner stated the helpful organic matter is largely removed before the water is pumped from the river.

II. *Presence in the Ohio River Water of Large Quantities of very Fine Clay Particles.*

From the statements and analyses of Chapter I, it is plain that the local river water contains widely varying amounts of sand, silt, and clay, and the water is never free of the latter.

These clay particles range in size from 1-10000 to 1-100000 inch, according to our measurements; and it is very probable that they would be found to be much smaller for a minimum range were microscopic facilities capable of such fine measurements in a satisfactory manner. In fact, there are reasons for believing that the clay particles approach a semi-liquid as well as submicroscopic condition.

Comparing again the local type of water with that of the Merrimack River, it is found that the occasional presence (to a material degree) of silt in the latter water, as well as the film-forming organic matter, is absent in the local water after it has been subsided for two or three days. There is present in the Ohio River water and absent in the Merrimack River water large quantities of clay, which at times become very great in amount and in the number of individual particles. In a measure these clay particles have gelatinous surfaces and adhere more or less firmly to the sand grains. This adhesiveness doubtless suffices to retain many bacteria and many clay particles which are very small when compared with the interstices of the sand layer. The retentive capacity of filters operating on the local water, however, is not only less than at the point noted in the east; but, in addition to the removal of bacteria, it is also necessary for them to retain clay particles far smaller than the bacteria.

It is in the presence for long periods of these vast quantities of minutest clay particles that the Ohio River water possesses one of the most characteristic differences from those waters which have been most carefully studied in connection with the English type of filtration.

III. *Imperfect Formation of Gelatinous Surface Coatings (Schmutzdecke) upon the Top of the Sand Layer.*

According to the teachings of the leading European writers upon filtration, the efficiency of English filters depends very largely, if not wholly, upon a gelatinous layer or coating at the surface of the sand layer. At Lawrence it was learned a number of years ago that such surface coatings were not indispensable for the satisfactory purification of the Merrimack River water, but that ordinarily the bulk of the work was undoubtedly done at and near the surface of the sand layer. More recently this fact has been appreciated somewhat by German writers, notably by Reinsch, who studied the operation of the Altona filters.

One of the most characteristic features of the English filters operated at Cincinnati was the comparative absence, with a few possible exceptions at times of very low and fairly clear water in the river, of such a gelatinous surface coating (Schmutzdecke) as is almost universally associated with filters of this type. This characteristic was best shown by inspection of the surfaces when the filters were drained prior to scraping. Instead of the well-defined gelatinous coating appearing as a uniform blanket or layer upon the sand surface, the surface had a more granular appearance; and closer inspection showed that there was almost nothing to be found except around the sand grains themselves. As referred to above, there were a few instances where the water was of such a character that the beginning of a surface layer formed by the suspended matter removed from the water could be noted. They were very exceptional, however. Of course, at the surface of the sand layer the grains were very dirty, and upon exposure after draining off the water the sun's rays would cause cracks from one quarter to one eighth

inch in depth. But in no instance did drying cause the surface to begin to peel, such as is conventionally noted with many municipal filters of the English type.

To those who did not see the surface of the sand filter it is ample proof of the granular, non-gelatinous, non-blanket appearance of the surface to note that the quantities of this very turbid water which were filtered between scrapings were abnormally large even for a water containing a far less amount of suspended matter.

In this connection it is very important to remember that, in addition to the comparative absence of a gelatinous surface coating at the top of the sand layer, there was also distinctly lacking in the water such organic matter as serves to form readily gelatinous films around those sand grains situated below the surface of the layer. When the Lawrence filters were deprived of the former by scraping, the latter were always present (except in very new filters), and with proper care sufficed to effect satisfactory purification. The Cincinnati filters were therefore doubly lacking to a marked degree in those natural factors upon which the efficiency of the process largely depends.

IV. *Deep Penetration of the Fine Clay Particles into the Sand Layer and its Influence upon the Depth of Scraping.*

When a water containing large numbers of minute clay particles of a size of 1-100000 inch and less is applied to a filter, which possesses only in a very limited way a gelatinous coating upon the surface of the sand layer, and in which the gelatinous films were largely lacking upon the sand grains beneath the surface, it is natural to expect that the fine clay particles would pass in large numbers into the sand layer. Experience with these filters quickly showed that this condition of affairs was perfectly true, as shown by the presence

of clay in the effluents of all the filters. Inspection of the sand layers at times of scraping, when the filters were only a few months old, demonstrated that the clay discolored the sand to depths of 4 to 6 and even 8 inches below the surface, but in a decreasing degree.

At the outset of these investigations the policy was adopted that in scraping these filters the upper portion of the sand layer should be removed so far as the sand was markedly dirty and discolored. When the filters were new and up to the early part of the summer this was a fairly simple procedure, because there was in all cases a well-defined plane separating the discolored sand and the cleaner sand beneath it.

The belief was held at the beginning that it was necessary to scrape these filters in this manner, in order to restore the frictional resistance of the sand layer to the normal, both in amount and uniformity; and that the sand grains at the new surface were sufficiently coated with accumulated materials from the water to maintain the efficiency of filtration, provided these coatings were of a proper character.

The investigations had not progressed very far before it was seen that this policy in scraping the filters was untenable. To carry it out in all cases it was found that in some instances it was necessary to scrape off 4 or 5 inches of sand from the surface at a single scraping, an amount which is impracticable on the ground of cost. Furthermore, the plane of demarcation practically disappeared after the turbid waters of the early summer were encountered, and it became practically impossible to locate the limit of discolored sand, as the clay gradually penetrated deeper and deeper into the sand layer. By this time it was also learned that the nature of the coatings upon the surface of the sand layer and around the grains beneath the

surface was not such that it could be depended upon uniformly to retain the suspended matters of the applied water either before or after scraping the filter.

Accordingly, on August 1, it was decided to scrape off about 1 inch or less at a time, regardless of the appearance of the sand beneath this plane.

V. *The Impracticability of allowing Loosened Portions of the Sand Layer at the Top to remain in the Filters.*

Owing to the method of filling these filters with sand, it was found that the sand layer was more compact near the center than towards the periphery of the tank. As it was desired to have the surface as level as possible, it was the custom in the spring, after scraping off the discolored portion, to level the new surface by moving some sand from the center and putting it nearer the periphery. It was soon found, however, under the local conditions already described, that the applied water passed through this loosened material without depositing its clay in a large measure; and in consequence the undisturbed sand beneath the loosened material was clogged and discolored almost as much as if it formed the surface itself, with the result that the depth of sand removed by scraping was increased above the normal by the amount of loosened material left on the surface from the preceding scraping.

Taken by itself, the above recorded observation is not of great practical significance. But when supplemented by more general observations it indicates, in our judgment, the probable impracticability at times when the applied water was very turbid of loosening the sand layer to increase its porosity, and of being able to restore the sand layer to its original thickness by the

addition of new or washed sand, without taking unusual care, or possibly first removing all the old sand down to the gravel layers. The reason of this lies in the prompt and serious clogging which would be likely to occur at the junction of the old or undisturbed surface and the new or disturbed material.

VI. *The Impracticability of using Acting Heads in Excess of the Depth of Water above the Sand (Negative Heads).*

It was the original plan to use as much acting head in operating these filters as economy and satisfactory qualitative results would allow. At Lawrence it was found that with filters operating upon the Merrimack River water the acting head could be safely carried to at least 5 feet in excess of the depth of water above the sand, while in the newest filters of this type in Germany a positive head of 2 feet, equal to only about one half of the depth of water above the sand, is used.

These experimental filters were constructed so that there was available a total head of about 13 feet, of which 4 feet were positive, and when new they were operated without scraping until the full available head was utilized. Without discussing the actual data which are presented beyond, it may be stated here, for the purpose of making clearer the operation of the filters, that such great acting heads were a failure under the local conditions. The reason of this was that the negative head (suction) reduced somewhat the pressure upon the water, which during much of the time is saturated (practically speaking) with air, thus causing the air to separate out gradually from the water as it becomes supersaturated at the reduced pressure. This separation of air took place for the most part

at and just below the section of maximum frictional resistance, which of course is at the surface of the sand layer. In consequence of the gradual separation and accumulation of air at this portion of the sand layer, it was found that the filter became clogged at a very rapid rate, comparatively speaking; and of the total quantity of filtered water with 13 feet of head only about 20 per cent of the volume was obtained with the 9 feet of negative head. As the filters grow older, it is probable that this percentage would be smaller.

This increased volume of water between scrapings of the filter was of course wholly inadequate to offset the increased cost of the construction and operation of filters with so great an available head. Furthermore, this method of operating filters was objectionable owing to the likelihood of the great acting head drawing clay down into the sand layer, which, with the probable formation to a greater or less degree of channels in the sand during the removal of the accumulations of air, favored the inadmissible condition of unequal rates of flow through different portions of the sand layer after the resumption of filtration following a scraping.

With reference to the local conditions conducing to the failure of negative heads, while they were successful at Lawrence, it is to be borne in mind that with the local filters the section of the sand layer which was more or less clogged by suspended matters from the water was thicker; and this very likely was a considerable factor, as it naturally would suggest that the accumulations of air took place in a portion of the sand layer that already was considerably clogged. Considering the fact that the Ohio River is well supplied with air, and at the same time is so highly charged with organic matter, it will be recalled that the increase in organic matter is always in

suspension when it becomes very large in amount, and that it is very stable in its character. From the evidence at hand it appears that, while a little oxygen may be used up in assisting nitrification, this process is so slow under the local conditions that its significance becomes almost *nil* when compared with experiences at Lawrence.

In passing, it may also be noted that it is impracticable to make the acting head before shutting off the applied water equal to the total head, owing to inability in removing satisfactorily the water which stands above and in the sand.

VII. *The Disturbances in an Irregular Manner of the Upper Portion of the Sand Layer, due to Various Forms of Animal Life contained in the Water.*

Reference was made in the last section to the inadmissibility of procedures facilitating unequal rates of filtration. In the operation of these experimental filters there were encountered conditions producing to a greater or less degree this objectionable state of affairs, which, so far as our knowledge upon the literature of the subject goes, have not been met with elsewhere. We refer to disturbances of the surface of the sand layer by various forms of animal life, notably fishes, angleworms, and water fleas.

Early in July it was noted in the case of two of the filters, Nos. 2 and 11, that the loss of head steadily decreased or remained about constant, when the character of the applied water was such that the friction of the sand layer should have increased quite rapidly. After such observations had been recorded for several days, it was decided to drain the filters, preparatory to an examination and scraping of the surface

of the sand layer. Inspection showed that the sand had been disturbed in an irregular manner at various places on the surface, which looked as if it had been raked to a very shallow depth. There were also noted upon the surface of the sand a number of small fishes from 1 to 2 inches in length.

During the month of July similar observations were made npon other filters, and both spoonbill and gar fishes were noted, the size of which varied and depended upon the period available for their growth. Taking all of the evidence into consideration, it seems clear that these fishes must have come from the applied water, and reached the filters either as spawn or fishes of very small size. Furthermore, this view is in perfect harmony with experiences at various pumping stations located on this river.

On July 25 a wire screen, having 20 meshes to the lineal inch, was placed over the mouth of the pipe conducting the subsided water into the regulating tank within the filter house. After this date no serious trouble was encountered from fishes; but it is by no means certain that the screen was a complete protection against them, as the absence of further trouble may have been due to the expiration of the spawning season.

At the time of the marked rise in the river, beginning about July 25, a new complication in the disturbance of the surface of the filters was noted. Losses of head were irregular, and, upon draining out the water, narrow winding channels of shallow depth were seen upon the surface. No signs of animal life were noted, and for some time we were puzzled to know the origin of these channels or furrows. However, by clarifying the water above the sand through the aid of sulphate

of alumina we were enabled to see a number of angleworms moving about and extending the typical furrows.

Relative to the origin of these angleworms, it is possible in filters Nos. 1 and 16 that they came in with the washed sand with which the filters were recently charged, but in the case of the other filters it is clear that they came from the applied water. This is quite natural, as heavy rains undoubtedly wash the eggs of angleworms into the river, and becoming attached to particles of clay or silt which were not removed by subsidence, they could have passed through the screen and into the filters, where they would find favorable conditions for reaching the sizes found. It also appears that their presence is dependent upon the season and the nature of the rainfall.

At the same time that the angleworms were discovered, it was noted that there were a number of water fleas moving about on the sand surface. They seemed to be disturbing the surface slightly, but it appears doubtful whether their presence was of much significance from a practical standpoint.

It is of course somewhat of an open question to what extent these surface disturbances produced by animal life would prove detrimental to the efficiency of filters in practice. In our opinion they would conduce to unequal rates of filtration, and in large filters the effect of these surface disturbances would probably be greater than in small filters, owing to opportunities for greater differences in the frictional resistance of the sand layer.

Independent of the degree to which these disturbances produced by these means would be detrimental in practice, it seems to be doubtful whether it would be possible to

keep all fishes and angleworms out of the filters; and their presence apparently can not be regarded as other than an objection to the applicability of this type of purification for the local water.

VIII. *The Imperativeness of guarding against the Formation of Vertical Channels in the Sand Layer and Disturbances of the Surface when filling a Filter after draining to Scrape it.*

This seems to be a self-evident proposition in the light of foregoing statements, and it is desired to record the fact that in every instance these experimental filters, after draining and scraping, were filled with water from below at substantially the same rate as was employed in the normal flow through the filter in the reverse direction. When the water stood several inches in depth above the surface of the sand, the application from below was stopped, and the subsided water was cautiously applied from the top so as not to cause surface disturbances. In this manner the interstices of the sand layer were freed of air uniformly and completely, practically speaking, without causing any channels or places of lessened resistance.

Up to about June 1 the side-filling pipes were used for applying the water beneath the sand layer. This was not thoroughly satisfactory, owing to inability to control the rate of flow. After this time the water was applied through the regular outlet pipe, and the flow controlled by meter measurement. Until the middle of September the water was taken from one of the other filters operated at the same rate as the one to be filled, but after that date the water was taken from the wash water tank used in connection with filter No. 20.

IX. *The Inadvisability of allowing Unpurified Water to reach the Lower Portions of a Filter, and the consequent Necessity of using Filtered Water for filling the Filters.*

From the standpoint of the quality of the effluent, and the seeding of the filter with hardy forms of bacterial life which may grow within the filter, it was considered poor practice to allow unfiltered water to enter the filters from below; and in no instance did this procedure take place after the filters were put in regular service.

X. *Efforts to Increase the Efficiency of the Filters by Means of Special Procedures.*

With the August rise in the river, when it had been clearly learned that the efficiency of the filters under normal conditions of operation was not uniformly satisfactory with regard to the removal of the fine clay, the policy was adopted of using special practical procedures to assist the filters when they were working at a disadvantage. The need of such steps arose, of course, at times of prolonged periods of marked turbidity in the applied subsided water. Efforts to aid the filters by retaining more completely the fine clay at and near the surface of the sand layer were made by the use of the following special procedures:

1. Scraping the filters when the loss of head reached about one half of the available positive head, or 2 feet.

2. Allowing the turbid water with which the filter above the sand was filled after scraping to settle for 12 to 24 hours, with the view to forming more or less of a sediment layer upon the surface of the sand.

3. Reducing the rate, upon the resumption of filtration

after scraping, to 50 to 60 per cent of the normal for 12 to 24 hours.

During the height of the August rise special procedures Nos. 2 and 3 were availed of to an unusual degree, extending beyond the first day following scraping.

The success which these special procedures met is considered in the next chapter after the presentation of the data obtained from their use.

INTERFERENCE OF FREEZING WEATHER IN THE SCRAPING OF ENGLISH FILTERS IN THIS LOCALITY.

In the operation of filter No. 13 during December, after the other original filters had been stopped, it was found that freezing weather with a mean temperature of less than 23° F. continued for about four days after the filter required scraping. Consequently the filter had to go out of service for this period, because it is a very serious matter to allow the upper portion of the sand layer to become frozen.

The question as to the practicability of operating satisfactorily uncovered filters in this locality during the winter is one of much significance. It is taken up at some length in the next chapter.

SUMMARY OF THE PRINCIPAL RESULTS OBTAINED FROM THE OPERATION OF THE FIFTEEN ORIGINAL EXPERIMENTAL FILTERS OF THE ENGLISH TYPE.

There now has been presented an account of the normal operation of these filters; a description of the special characteristics in connection with the composition of the local water; and an outline of regular and special procedures adopted to assist them at times of scraping. It remains to

place on record a summary of the principal results accomplished by these filters.

As a matter of convenience the records of the daily operation of each filter (including the quantity of water filtered, the loss of head, the individual results of chemical and bacterial analyses of the effluents, the appearance of the effluents, and the percentages of organic matter and of bacteria removed) are presented in Appendix I. From these records a number of tabulations of data relative to special points are given in the discussion of these filters in the next chapter.

In the following pages the principal evidence in concise tabular form is presented upon the following points:

1. The scraping of the filters with reference to the volume of water obtained between scrapings, the depth of material removed, the condition of the scraped surface, and a record of special procedures if such were adopted.

2. The influence upon the bacterial efficiency of the filters of scraping the surfaces, under the condition stated in the first tabulation, as shown by the results of series of special bacterial analyses in the case of each scraping.

3. A summary of the leading quantitative and qualitative data obtained from each filter, arranged in the form of monthly averages, with percentages of removal.

Preceding the actual data the following explanation of these three tables is given:

Table No. 1.

In this table are presented all of the leading quantitative results of operation of the filters, arranged and averaged by periods. In the case of filters Nos. 3, 6, 9, 11, 12, and 15, the last period was not completed, the filter having been taken out of service before it was ready to scrape. In these

cases partial data are presented. The data of filter No. 13 after November 17 are not presented because of complications from freezing.

The several terms used and the methods of calculation are as follows:

Period.—A period includes all of the operations of a filter from the time the outlet is first opened following a scraping until it is again opened after the next scraping, the time of opening the outlet (the beginning of filtration) being taken as the date of the beginning of the period.

Length of Period.—The length of the period is the length of time covered by the period excluding all delays not consequential to the normal operation of the filters.

Loss of Head.—These observations show the minimum and maximum loss in pressure or head of the water in passing through the sand layer.

Rate of Filtration.—Under this heading are presented notes on changes in the rate of filtration, and also the average rate during normal filtration—that is, from the time filtration was started until draining of the filter was begun, preparatory to scraping. The net rate of filtration is the result of dividing the total quantity of water filtered by the total length of the period. All results are expressed in the conventional form of million gallons per acre per day. They may be transferred to U. S. gallons per square foot per hour by multiplication by 0.96, to vertical velocity in meters per 24 hours by multiplication by 0.94, or to vertical velocity in millimeters per hour by multiplying by 39.0.

Quantity of Effluent.—The quantity of water filtered during the period is given in million gallons per acre, the actual quantities on the experimental filters having been multiplied by 400, as each filter was 0.0025 acre in area.

Sand Removed.—The amount of sand removed is expressed in the thickness of the layer; the equivalent in cubic yards per acre; the cubic yards per million gallons of effluent; and the cubic yards per ton of applied suspended matter. The method of computation of these results is evident from their character.

Subsided Water above Sand settled after Scraping.—As described above, it was customary for a short time during these tests to let the filter stand after scraping, with the space above the sand filled with water for several hours before starting filtration. The periods so occupied are presented in this column.

Table No. 2.

In this table are presented the results of special bacterial analyses of the filtered water to learn the effect of scraping, and the averages of the regular bacterial analyses of the effluent for the day of and for two days before and after scraping are also given for the sake of comparison. The average for the day of scraping was obtained from all samples collected on that day, giving weight to the quantity of water which each sample represented.

For the purpose of obtaining special data directly after scraping, which should be directly comparable in the case of the several filters operated at different rates of filtration, the special samples were collected uniformly after the passage of stated quantities of effluent following the opening of the outlet, and not after stated periods had elapsed, as is more customary. The periods of time after opening the outlet, however, corresponding to the stated quantities of effluent for the different rates, are given in the following table as a matter of record:

Periods of Time in Hours corresponding to the Several Stated Quantities of Effluent, at which Special Bacterial Samples were collected for the Different Rates of Filtration.

Rate of Filtration.	Hours Corresponding to the Following Quantities of Effluent in Million Gallons per Acre.						
Million Gallons per Acre Daily.	0.15	0.27	0.39	0.51	0.63	0.87	1.20
1.5	0.24	0.43	0.62	0.81	1.01	1.39	1.92
2.6	0.14	0.25	0.36	0.47	0.58	0.80	1.11
4.0	0.09	0.16	0.23	0.31	0.38	0.52	0.72

In recording the results of quantitative bacterial examinations it was decided that all results should be expressed in only such figures as the mathematical accuracy of the methods warranted. This had been found by long series of observations to be not less than 5 per cent, and accordingly throughout this report all observations are recorded as follows:

Number of Bacteria per Cubic Centimeter.	Recorded to.
1– 50	Nearest unit.
51– 100	" five.
101– 250	" ten.
251– 500	" twenty-five.
501–1,000	" fifty.
1,001 and over	" hundred.

Table No. 3.

This table contains monthly averages of the principal results of operation of the fifteen original filters, including the quantities of water filtered (net rates of filtration); the suspended matter (clay) in parts per million contained in the

water before and after filtration; the total organic matter before and after the water was filtered, with percentages of removal; and the number of bacteria per cubic centimeter in the subsided water and the effluents, with the bacterial efficiency.

In the column under the heading of organic matter the upper set of figures refers to nitrogen in the form of albuminoid ammonia, while the lower set represents oxygen consumed. As explained in Chapter I, these two determinations represent nitrogenous and carbonaceous organic matter, respectively.

Concerning the parts per million of suspended matter in the effluent, this is the form adopted of expressing the turbidity of the effluents. The results were regularly obtained by comparing the effluents in Nessler cylinders of white glass with waters containing known quantities of river clay. In a measure, variations at times in the color of the clay in the effluents as compared with that of the standards interfered somewhat with the accuracy of the estimates, but this was compensated for so far as practicable by the use of artificial coloring of some of the standards. By reason of the variations in the character of the clay particles, usually too small to be weighed accurately, these optical results are to be regarded as approximate estimates and not accurate determinations. However, they serve well for purposes of comparison with each other and with the corresponding data for the subsided water.

It was decided in the course of this work that all effluents containing 7 or more parts per million of suspended clay were too turbid to be satisfactory in appearance.

In places in this report the term "degree of clearness" is used, as was the case in the Louisville investigations. The

several degrees correspond to parts of suspended clay and in general appearance as follows:

Degree of Clearness.	Range in Parts of Clay.	General Appearance.
1	Under 1	Brilliant.
2	1- 2	Clear.
3	3- 6	Slightly turbid.
4	7-15	Turbid.
5	Over 15	Very turbid.

As follows from the statements above, the effluents were satisfactory in appearance when they possessed either of the first three degrees of clearness, and unsatisfactory when they had either of the two last degrees.

The daily observations from which these averages were computed will be found in Appendix I, where it will be noted that the organic matter was determined in representative samples covering three days each, and in some instances four days. The same is true for the other chemical results, excepting the suspended matter. Of the several chemical constituents not averaged in Table No. 3, there were practically no changes during filtration in the chlorine; sulphuric acid; incrusting constituents (permanent hardness); alkalinity (temporary hardness); and carbonic acid. The dissolved oxygen in some instances, however, was materially lessened, notably in hot weather, but never exhausted. Changes in the several forms of oxidized nitrogen are discussed in Chapter V.

TABLE No. 1—*Summary of Quantitative Results of Operation of English Filters arranged by Periods.*

Period. Number.	Began. 1898.	Length. Days.	Average Parts per Million of Applied Suspended Matter.	Loss of Head. Feet. Initial.	Final.	Condition of Sand Surface before Scraping.	Rate of Filtration in Million Gallons per Acre Daily. Reduced Initially. To.	For Hours.	Averages. Actual.	Net.	Quantity of Effluent in Million Gallons per Acre.	Sand Removed. Thickness of Layer in Inches.	Volume in Cubic Yards. Per Acre of Surface.	Per Million Gallons of Effluent.	Per Ton of Applied Suspended Matter.	Subsided Water above Sand, settled after Scraping, Hours.
Filter No. 1.																
1	March 28	29.50	55	0.2	13.0	Air holes.....	.....	.....	2.61	2.50	73.74	0.78	105	1.42	6.2	504.0
2	April 27	29.35	53	0.2	4.0	Normal	.....	....	2.63	2.56	75.14	1.92	258	3.44	14.9	0.0
3	May 27	29.30	29	0.1	4.2	Normal	....	.....	2.68	2.58	82.80	1.12	150	1.81	14.9	0.0
4	June 28	29.04	56	0.1	3.5	Granular.....	.....	.....	2.58	2.50	72.70	0.67	90	1.23	5.3	0.0
5	July 27	17.60	136	0.1	3.5	Disturbed	.....	.....	2.57	2.10	36.84	1.00*	133	3.61	6.3	0.0
Filter No. 2.																
1	March 28	34.80	51	0.1	13.0	Air holes...	.....	.....	2.51	2.44	84.86	0.90	121	1.43	6.7	504.0
2	May 2	42.94	51	0.2	4.0	Normal	.....	.....	2.64	2.59	11.68	3.06	408	3.67	17.2	0.0
3	June 14	24.86	41	0.1	1.0†	Badly disturbed.....	.....	.....	2.64	2.59	64.30	0.31	42	0.65	3.8	0.0
4	July 9	28.67	85	0.1	2.1‡	Pitted	....	.....	2.63	2.62	76.60	1.00	133	1.74	4.8	0.0

* Entire sand layer removed and filter taken out of operation. † Maximum 1.6 feet. ‡ Maximum 2.2 feet.

Filter No. 3.

1	March 28	37.68	55	0.1	13.0	Normal	....	.....	2 60	2.54	95.70	1.26	169	1.75	7.8	504.0
2	May 5	28.54	59	0.2	1.4	Normal	.....	.....	2.63	.....	75.72	.....	... ..	.....	....	0.0

Filter No. 4.

1	March 28	29.71	62	0.5	13.0	Air holes.....	.....	....	3.89	3.68	109.49	0.65	87	0.79	3.1	504.0
2	April 26	15.90	41	0.5	4.0	Normal	...	.....	3.90	3.82	60.80	1.79	242	3.97	23.0	0.0
3	May 12	22.39	61	0.4	4.0	Normal	.....	.....	4.18	4.02	89.99	2.71	364	4.05	15.8	0.0
4	June 4	22.20	21	0.3	4 0	Normal	.....	.....	4.00	3.87	91.50	0 78	104	1.13	12.9	0.0
5	June 27	27.06	48	0.3	4.0	Granular	.....	.....	4.00	3.82	103.40	2.28	307	2.92	14.8	0.0
6	July 24	16.54	136	0.2	1.2	Badly pitted.....	.....	....	4.02	3.65	60.36	1.00	134	2.23	3.9	0.0
7	Aug. 10	5.63	230	0.5	0.6	Badly disturbed.....	2.6	24.0	3.25	2.51	15.07	0.65	88	5.81	6.1	9.0
8	Aug. 16	11.84	134	0.7	2.0	Granular, pitted....	2.6	48.0	3.66	3.15	37.26	0.54	73	1.96	3.5	13.0
9	Aug. 28	11.08	57	0.7	2.0	Granular	2 6	24.0	3 88	3.40	40.43	0.77	104	2.57	10.9	20.2
10	Sept. 9	13.72	13	0.7	4.0	Disturbed	2.6	72.0	3.75	3.72	50.99	1.08	146	2.87	52 9	20.5

Filter No. 5.

1	March 28	34.77	57	0.2	13.0	Normal	.....	....	3.96	3.92	133.62	0.84	113	0.84	3 6	504.0
2	May 2	35.75	58	0.2	4.0	Normal	.....	...	4.05	3.96	140.92	4.38	590	4.18	17.2	0.0
3	June 7	24.97	25	0 2	4.0	Normal	...	.....	4.04	3.93	98.00	0.86	116	1.18	14.2	0.0
4	July 2	33.08	78	0.2	1.8	Badly pitted	....	.....	4.01	3.97	131.07	1.15	155	1.18	3.6	0.0
5	Aug. 5	8.00	130	0.4	0.5	Badly pitted	....	.....	3 93	3.25	25.98	1.11	150	5.76	10.6	0.0
6	Aug. 13	10 96	170	0.3	1.1	Disturbed	2.6	72.0	3.60	3.45	37.76	1.00	133	3.57	5.0	9.0

TABLE No. 1—*Summary of Quantitative Results of Operation of English Filters arranged by Periods*—(Continued).

Period. Number.	Began. 1898	Length. Days.	Average Parts per Million of Applied Suspended Matter.	Loss of Head. Feet. Initial.	Final.	Condition of Sand Surface before Scraping.	Rate of Filtration in Million Gallons per Acre Daily. Reduced Initially. To.	For Hours.	Averages. Actual.	Net.	Quantity of Effluent in Million Gallons per Acre.	Sand Removed. Thickness of Layer in Inches.	Volume in Cubic Yards. Per Acre of Surface.	Per Million Gallons of Effluent.	Per Ton of Applied Suspended Matter.	Subsided Water above Sand, settled after Scraping, Hours.
						Filter No. 6.										
1	March 28	35.61	57	0.2	13.0	Air holes.....	... ..	.....	3.94	3.84	136.97	2.37	319	2.33	9.80	504.0
2	May 3	30.61	60	0.3	2.8	Normal	.....	.....	4.02	.....	123.04	.....	.....	.....	.....	.....
						Filter No. 7.										
1	March 28	35.61	57	0.3	13.0	Air holes.....	.....	.....	2.61	2.52	89.81	0.86	115	1.28	5.4	504.0
2	May 3	31.34	59	0.3	4.0	Normal	.....	.....	2.60	2.57	80.40	2.08	280	3.49	14.1	0.0
3	June 4	21.42	20	0.3	4.2	Normal	.....	.....	2.68	2.55	61.80	0.61	81	1.31	15 7	0.0
4	June 28	32.96	62	0.2	4.0	Normal	.....	.....	2.61	2.55	84.00	2.15	289	3.44	13.3	0.0
5	July 31	15.60	174	0.2	0.7	Slightly pitted.....	1.5	24.0	2.64	2.24	35.04	0.57	76	2.18	2.9	5.4
6	Aug. 16	20.37	106	0.3	2.0	Normal	1.5	24.0	2.45	2.19	46.60	0.83	112	2.40	5.3	22.0
7	Sept. 6	14.19	13	0.3	4.0	Granular.....	.....	.....	2.53	2.42	34.33	0.71	96	2.78	51.7	0.0

Filter No. 8.

1	March 28	36.83	56	0.2	13.0	Air holes.....	.....	.....	2.60	2.52	92.79	1.08	145	1.57	6 7	0.0
2	May 4	44.69	49	0.2	4.0	Normal	.....	.....	2.62	2.58	114.97	2.72	363	3.16	15.4	0.0
3	June 18	34.60	39	0.1	4.0	Slightly disturbed....	.....	.....	2.55	2.52	87.10	2.05	277	3.17	19.5	0.0
4	July 23	21.10	138	0.2	0.5	Pitted	.....	.....	2.56	2.40	50.62	1.36	183	3.62	6.3	0.0
5	Aug. 13	10.96	181	0 1	0.7	Disturbed	1.50	72.0	2.27	2.23	24.77	1.00	135	5.41	7.2	0.0

Filter No. 9.

1	March 28	37.67	55	0.2	13 0	Air holes.....	.....	.....	2.60	2.49	93.63	1.30	174	1.86	8.1	504.0
2	May 5	28.55	59	0.3	1.4	Normal	.....	.....	2.67	.....	76.20	.....	.....	.....	.....	0.0
3	Aug. 1	30.66	147	0.2	0.3	Badly disturbed.....	.....	.....	2.44	.....	74.80	.....	.....	.....	.....	0.0

Filter No. 10.

1	March 28	45.83	55	0.2	13.0	Air holes.....	.....	.....	1.56	1.48	67.88	0.72	97	1.43	6.2	504.0
2	May 13	41.34	41	0.1	4.0	Normal	.....	.....	1.61	1.59	68.50	0.95	128	1.84	11.5	0.0
3	June 25	32.10	54	0.1	4.0	Granular.....	.....	.....	1.52	1.50	47.90	1.17	158	3.29	14.6	0.0

Filter No. 11.

1	March 28	46.74	55	0.1	13.0	Normal.....	.....	.....	1.54	1.48	69.25	0.75	100	1.45	6.3	504.0
2	May 14	56.13	47	0.1	0.3	Badly disturbed.....	.....	.....	1.54	1.53	85.90	1.43	191	2.22	11.4	0.0
3	July 8	22.33	64	0.1	0.2	Disturbed	.....	.....	1.54	.....	34.68	.....	.....	.....	.....	0.0

TABLE No. 1—*Summary of Quantitative Results of Operation of English Filters arranged by Periods*—(Concluded).

Period. Number.	Began. 1898.	Length. Days.	Average Parts per Million of Applied Suspended Matter.	Loss of Head. Feet. Initial.	Final.	Condition of Sand Surface before Scraping.	Rate of Filtration in Million Gallons per Acre Daily. Reduced Initially. To.	For Hours.	Averages. Actual.	Net.	Quantity of Effluent in Million Gallons per Acre.	Sand Removed. Thickness of Layer in Inches.	Volume in Cubic Yards. Per Acre of Surface.	Per Million Gallons of Effluent.	Per Ton of Applied Suspended Matter.	Subsided Water above Sand, settled after Scraping, Hours.
Filter No. 12.																
1	March 28	49.70	55	0.2	13.0	Air holes.....	.....	.....	1.54	1.51	74.91	0.94	126	1.68	7.3	504.0
2	May 17	16.57	72	0.1.	0.2	Slightly disturbed ..	.....	.....	1.55	.....	25.65	.....	.....	.....	.....	0.0
Filter No. 13.																
1	March 28	36.81	56	0 4	13.0	Normal	.....	.....	2.58	2.52	92.58	1.04	140	1.51	6.5	504.0
2	May 4	33.90	53	0.3	4.0	Normal	.. ...	.....	2.63	2.59	87.75	1.75	235	2.68	11.0	0.0
3	June 7	25.28	16	0.2	4.0	Slightly disturbed....	.....	.....	2.62	2.60	65.58	1.09	146	2.28	17.7	0.0
4	July 3	31.97	76	0.2	1.7	Disturbed	....	.....	2.60	2.55	81.59	2.52	340	4.20	13.1	0.0
5	Aug. 4	9.26	138	0.3	2.0	Badly disturbed.....	.....	.....	2.57	2.23	20.57	0.94	127	6.17	10.7	0.0
6	Aug. 13	14.88	153	0.3	2.0	Granular	1.50	24.0	2.35	2.10	31.30	0.52	71	2.27	3.5	12.0
7	Aug. 28	14.05	47	0.5	2.0	Slightly disturbed....	....	....	2.56	2.30	34.28	0.74	100	2.92	14.9	21.0
8	Sept. 12	21.22	16	0.5	4.0	Normal	....	.....	2.67	2.51	53.14	0.51	69	1.30	19.6	0.0
9	Oct. 3	27.87	22	0.5	4.0	Normal	.....	.....	2.63	2.60	72.21	0.83	112	1.55	17.0	0.0
10	Oct. 31	17.62	67	0.8	4 0	Normal	1.50	24.0	2.59	2 12	42.47	0.83	112	2.63	9.4	12.7

Filter No. 14.

1	March 28	37.68	55	0.3	13.0	Normal	.....	.....	2.58	2.55	96.14	1.13	152	1.59	6.9	504 0
2	May 5	41.91	51	0.3	4.0	Normal	.....	.....	2.63	2.61	108.98	2.27	304	2.78	13.2	0 0
3	June 16	35.55	40	0.2	4 0	Slightly disturbed.....	.....	.....	2.66	2.59	91.90	1 67	223	2.42	14 5	0.0
4	July 23	21.68	135	0.2	0 8*	Disturbed	.....	.....	2 62	2.46	53.32	1.14	153	2.88	5.1	13.0
5	Aug. 13	16.62	138	0.2	1 5	Slightly disturbed..	1.50	72.0	2.37	2.12	35.19	0.59	80	2.27	3.9	18.0

Filter No. 15.

1	March 28	36.81	59	0.3	13.0	Normal	.....	.....	2.61	2 53	92.93	1.47	198	2.14	9.1	0.0
2	May 4	29.42	55	0.3	1.7	Normal	.....	.....	2.64	.....	77.79	.....	61	.....	... ...	0.0

*Maximum 1.3 feet.

TABLE No. 2 — *Results of Bacterial Examinations of Effluents, to Show the Effect of Scraping.*

Bacteria per Cubic Centimeter.

Date of Scraping. 1898	Average Results of Regular Samples on Days Preceding Scraping		Special Results after Passage of Stated Quantities of Effluent in Million Gallons per Acre after Scraping.								Average Results of Regular Samples.		
											Day of Scraping.	Days after Scraping.	
	Second.	First.	0.15	0.27	0.39	0.51	0.63	0.87	1.20	Ave.		First.	Second.
Filter No. 1.													
April 27	150	110	400	325	350	350	325	350	325	350	325	230	210
May 27	80	80	170	190	100	90	85	110	100	120	120	140	110
June 28	19	41	40	37	23	50	47	39	60	42	41	80	60
July 27	30	35	80	95	210	170	120	170	65	130	65	275	100
Filter No. 2.													
May 2	150	210	325	300	400	600	300	500	160	350	400	375	220
June 14	39	31	70	48	46	46	38	49	50	50	49	110	60
July 9	65	65	140	130	150	210	170	250	220	180	175	160	70

Filter No. 3.

May 5.....	120	130	150	200	220	200	95	95	80	150	190	160	180

Filter No. 4.

April 26.....	100	110	425	450	450	325	325	325	400	400	350	450	230
May 12....	190	160	150	160	170	200	180	190	180	180	180	210	120
June 3.....	48	45	75	65	44	90	70	60	65	70	50	85	39
June 27.....	28	....	70	80	43	50	40	43	33	50	65	34	45
July 24.....	16	18	130	120	65	275	120	110	110	130	100	130	70
Aug. 10.....	65	75	800	130	48	1,200	95	650	180	450	500	80	60
Aug. 16.....	60	85	49	38	70	46	55	65	275	85	90	110	110
Aug. 28.....	45	25	27	48	75	38	32	36	26	40	55	42	55
Sept. 9.....	27	22	22	9	7	14	13	13	18	14	12	16	27

Filter No. 5.

May 2.....	170	250	220	425	170	375	250	350	180	275	350	300	170
June 7.....	41	38	65	60	33	39	29	31	28	41	60	110	160
July 2.....	22	30	65	70	400	1,100	400	325	300	375	65	60	80
Aug. 5.....	50	46	80	48	85	75	60	90	60	70	85	110	100
Aug. 13.....	70	60	60	85	120	100	100	110	220	110	130	200	150

TABLE No. 2 — *Results of Bacterial Examinations of Effluents, to Show the Effect of Scraping*—(Continued).

Bacteria per Cubic Centimeter.

Date of Scraping. 1898	Average Results of Regular Samples on Days Preceding Scraping.		Special Results after Passage of Stated Quantities of Effluent in Million Gallons per Acre after Scraping.								Average Results of Regular Samples.		
											Days of Scraping.	Days after Scraping.	
	Second.	First.	0.15	0.27	0.39	0.51	0.63	0.87	1.20	Ave.		First.	Second.
Filter No. 6.													
May 3	140	220	210	210	200	250	275	180	230	220	225	170	90
Filter No. 7.													
May 3	200	140	170	210	210	240	160	150	230	200	200	180	110
June 3	55	40	95	85	100	80	75	80	85	90	75	60	46
June 28	19	55	36	55	42	41	60	43	50	47	41	60	39
July 31	26	25	55	75	325	450	50	40	39	150	90	75	44
Aug. 16	55	44	37	110	50	65	200	425	80	140	75	110	100
Sept. 6	36	19	29	33	88	32	35	36	85	41	31	55	38
Sept. 20	22	32	80	85	75	95	24	28	85	65	70	100	41

Filter No. 8.

May 4	100	220	220	180	170	170	230	200	150	190	300	125	80
June 18	33	39	80	220	80	95	28	150	250	125	100	240	130
July 22	55	55	75	130	325	350	250	130	325	230	190	65	75
Aug. 13	60	55	100	120	90	110	150	150	120	120	110	180	130

Filter No. 9.

May 5	120	150	110	150	140	120	130	95	130	120	130	120	160
Aug. 1	....	....	700	650	475	600	2,200	700	700	850	800	950	275

Filter No. 10.

May 13	210	120	120	120	140	150	200	190	170	150	120	150	70
June 25	32	42	....	....	....	....	....	....	....	....	....	120	80
July 27	12	20	39	42	43	50	41	36	75	47	39	55	25

Filter No. 11.

May 14	150	190	250	130	300	140	190	170	210	200	190	200	300
July 9	70	90	110	110	110	75	160	190	1,400	300	425	1,400	425

Filter No. 12.

May 17	250	120	160	110	95	110	110	90	70	110	125	160	110

TABLE No. 2 — *Results of Bacterial Examinations of Effluents, to Show the Effect of Scraping*—(Concluded).

Bacteria per Cubic Centimeter.

Date of Scraping. 1898	Average Results of Regular Samples on Days Preceding Scraping.		Special Results after Passage of Stated Quantities of Effluent in Million Gallons per Acre after Scraping.								Average Results of Regular Samples.		
											Days of Scraping.	Days after Scraping.	
	Second.	First.	0.15	0.27	0.39	0.51	0.63	0.87	1.20	Ave.		First.	Second.
Filter No. 13.													
May 4	300	250	200	240	190	300	300	250	220	240	190	140	70
June 7	34	22	25	27	40	44	27	39	27	33	20	23	31
July 2	10	13	19	12	15	11	18	100	120	41	46	47	38
Aug. 4	21	15	15	23	20	15	17	16	25	19	23	32	42
Aug. 13	28	19	15	23	21	25	70	43	38	33	19	40	60
Aug. 28	24	34	55	19	24	55	26	26	36	34	40	25	46
Sept. 12	14	16	95	110	110	60	90	90	44	85	85	37	35
Oct. 3	15	11	29	22	26	18	29	31	19	25	17	27	27
Oct. 31	26	34	25	22	46	65	85	75	100	60	75	80	65
Nov. 18	100	110	60	49	90	90	80	90	120	85	80	90	130
Dec. 13	275	1,000	210	650	750	1,700	800	800	1,400	900	600	350	450

Filter No. 14.

May 5.....	60	240	140	160	200	210	180	110	85	150	170	85	95
June 16.....	48	33	34	31	55	35	110	47	60	55	32	43	32
July 22.	26	44	90	100	100	70	50	50	70	75	80	42	50
Aug. 13.....	50	45	33	50	25	47	80	75	50	50	50	325	130

Filter No. 15.

May 4.....	95	140	200	200	180	240	210	200	170	200	190	120	75

TABLE No. 3.

Summary of the Leading Qualitative Results of Operation of English Filters, arranged by Months.

Filter No. 1.

Month. 1898.	Temperature of Effluent. Deg. C.	Rate of Filtration. Million Gallons per Acre Daily.	Suspended Matter. Parts per Million.		Total Organic Matter.* Parts per Million.		Percent. Removal.	Bacteria per Cubic Centimeter.		Bacterial Efficiency.
			Subsided Water.	Effluent	Subsided Water.	Effluent.		Subsided Water.	Effluent.	
April	10.0	2.47	60	15	.141 2.9	.092 2.0	34.8 31.0	5,400	750	86.1
May	17.0	2.52	59	11	.153 3.1	.082 2.0	46.4 35.5	3,900	100	97.4
June	23.5	2.57	27	4	.115 2.2	.067 1.4	41.8 36.4	850	31	96.4
July	26.5	2.51	67	9	.143 2.6	.082 1.6	42.6 38.5	2,200	55	97.5
August	25.5	2.61	147	20	.197 3.3	.087 1.8	55.9 45.5	3,000	75	97.5

Filter No. 2.

April	10.0	2.56	60	16	.142 2.9	.096 1.9	33.4 34.5	5,400	700	87.0
May	17.0	2.51	59	15	.153 3.1	.095 2.1	37.9 32.3	3,900	140	96.4
June	23.5	2.59	27	4	.115 2.2	.070 1.5	39.1 31.8	850	37	95.6
July	26.5	2.58	67	11	.143 2.6	.085 1.7	40.5 34.6	2,200	85	96.1
August	26.0	2.62	166	23	.200 3.4	.093 2.0	53.5 41.2	2,500	100	96.0

Filter No. 3.

April	10.0	2.64	60	25	.141 2.9	.091 2.1	33.4 27.6	3,400	800	85.2
May	17.0	2.57	59	15	.153 3.1	.093 2.1	39.2 32.3	3,900	160	95.9

* The first (upper) figures in each bracket represent the nitrogenous matter (nitrogen as albuminoid ammonia) and the second (lower) the carbonaceous matter (oxygen consumed).

TABLE No. 3—*Summary of the Leading Qualitative Results of Operation of English Filters, arranged by Months*—(Continued).

Filter No. 4.

Month. 1898.	Temperature of Effluent. Deg. C.	Rate of Filtration. Million Gallons per Acre Daily.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Percent. Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent.	Bacterial Efficiency.
April..	10.0	3.82	60	13	.141 2.9	.090 1.9	36.2 34.5	5,400	800	85.2
May.....	17.0	4.00	59	8	.153 3.1	.088 1.8	45.7 42.0	3,900	95	97.5
June	23.5	3.84	27	3	.115 2.2	.066 1.3	42.6 41.0	850	33	96.1
July.	26.5	3.86	67	7	.143 2.6	.078 1.5	45.4 42.3	2,200	40	98.2
August.....	26.5	3.30	147	21	.189 3.8	.097 2.1	48.6 44.8	3,000	80	97.3
September...	23.5	3.55	22	5	.133 2.8	.088 1.8	33.8 35.7	1,700	24	98.6

Filter No. 5.

April.. ...	10.0	3.97	60	15	.141 2.9	.089 1.8	36.9 38 0	5,400	800	85.2
May.....	17.0	3.92	59	10	.153 3.1	.84 1.8	45.0 42.0	3.900	110	97.2
June	23.5	3.89	27	3	.115 2.2	.067 1.3	41.7 41.0	850	46	94.6
July.....	26.5	3.95	67	8	.143 2.6	.078 1.5	45 4 42.8	2,200	50	97.7
August. ..	25.0	3.52	180	24	.198 3.9	.103 2.1	48.0 48.2	3,400	110	96.8

Filter No. 6.

April.....	10.0	3.96	60	17	.141 2.9	.092 1.9	34.8 34.5	5,400	650	88.0
May.	17.0	3.87	59	12	.153 3.1	.084 1.9	45.0 38.7	3,900	100	97.4

Filter No 7.

April..	10.0	2.61	60	11	.141 2.9	.086 1.8	39.0 38.0	5,400	850	84.2
May.....	17.0	2.51	59	8	.153 3.1	.079 1.7	48.3 45.2	3,900	100	97.4
June.... ...	23 5	2.48	27	3	.115 2.2	.063 1.2	45.2 45.5	850	36	95.8
July.	26.5	2.55	67	5	.143 2.6	.070 1.4	51.0 46.2	2,200	36	98.4
August.....	26.5	2.32	147	18	.189 3.8	.090 2.0	52.4 47.3	3,000	55	98.2
September...	23.0	2.31	22	4	.131 2.7	.084 1.8	35.8 33.8	1,800	33	98.2

TABLE No. 3—*Summary of the Leading Qualitative Results of Operation of English Filters, arranged by Months*—(Continued).

Filter No. 8.

Month. 1898.	Temperature of Effluent. Deg. C.	Rate of Filtration. Million Gallons per Acre Daily.	Suspended Matter. Parts per Million.		Total Organic Matter. Parts per Million.		Percent. Removal.	Bacteria per Cubic Centimeter.		Bacterial Efficiency.
			Subsided Water.	Effluent.	Subsided Water.	Effluent.		Subsided Water.	Effluent.	
April	10.0	2.60	60	18	.141 2.9	.083 1.8	41.2 38.0	5,400	850	84.2
May	17.0	2.57	59	10	.153 3.1	.081 1.8	47.0 42.0	3,900	120	96.9
June	23.5	2.50	27	3	.115 2.2	.066 1.3	42.6 41.0	850	50	94.1
July	26.5	2.52	67	7	.143 2.6	.075 1.5	47.5 42.3	2,200	50	97.7
August	25.0	2.28	180	22	.199 3.9	.095 2.0	52.2 48.7	3,400	85	97.5

Filter No. 9.

April	10.0	2.59	60	15	.141 2.9	.094 1.9	33.4 34.5	5,400	600	88.9
May	17.0	2.21	59	12	.153 3.1	.083 1.8	45.7 42.0	3,900	110	97.2
August	26.5	2.47	147	22	.189 3.8	.099 2.1	47.6 44.8	3,000	190	93.7

Filter No. 10.

April	10.0	1.56	60	10	.141 2.9	.084 1.6	40.5 34.8	5,400	900	83.3
May	17.0	1.46	59	6	.153 3.1	.075 1.5	50.9 51.6	3,900	100	97.4
June	23.5	1.52	27	3	.115 2.2	.063 1.2	45.2 45.5	850	39	95.4
July	26.5	1.49	67	3	.143 2.6	.066 1.3	53.8 50.0	2,200	25	98.9

Filter No. 11.

April	10.0	1.58	60	12	.141 2.9	.083 1.7	41.2 41.4	5,400	1,000	81.5
May	17.0	1.51	59	6	.153 3.1	.075 1.6	50.9 48.4	3,900	130	96.7
June	23.5	1.55	27	2	.115 2.2	.065 1.2	43.5 45.5	850	39	95.4
July	26.5	1.52	67	3	.143 2.6	.069 1.4	51.7 46.2	2,200	140	93.6

Filter No. 12.

April	10.0	1.53	60	16	.141 2.9	.088 1.8	37.6 38.0	5,400	950	82.4
May	17.0	1.50	59	10	.153 3.1	.079 1.7	48.3 45.2	3,900	120	96.9

TABLE No. 3—*Summary of the Leading Qualitative Results of Operation of English Filters, arranged by Months*—(Concluded).

Filter No. 13.

Month. 1898.	Temperature of Effluent. Deg. C.	Rate of Filtration. Million Gallons per Acre Daily.	Suspended Matter. Parts per Million.		Total Organic Matter. Parts per Million.		Percent. Removal.	Bacteria per Cubic Centimeter.		Bacterial Efficiency.
			Subsided Water.	Effluent.	Subsided Water.	Effluent.		Subsided Water.	Effluent.	
April	10.0	2.55	60	9	.141 2.9	.074 1.6	47 5 34.8	5,400	700	87.0
May	17.0	2.56	59	5	.153 3.1	.069 1.5	54.8 51.6	3,900	100	97.4
June	23.5	2.59	27	2	.115 2 2	.058 1.1	49.6 50.0	850	21	97.5
July	26.5	2.58	67	2	.143 2.6	.063 1.3	55.9 50.0	2,200	19	99.1
August	26.5	2.19	147	12	.189 3.8	.083 1.7	56.1 55.3	3,000	35	98.8
September	23.0	2.53	21	3	.130 2.6	.075 1.5	42.3 42.3	2,200	24	98.9
October	16.0	2.49	22	1	.114 2 0	.062 1.1	40.4 45.0	3,200	17	99.4
November	7.0	2.44	59	9	.179 4.3	.094 2.4	47.6 44.2	10,400	75	99.3
December	1.5	1.94	72	10	.184 3.4	.092 1.9	50.1 44.1	23,100	1,000	95.7
1899.										
January	2.5	1.86	117	13	.248 4.6	.099 2.1	60.0 54.4	16,500	550	96.7

Filter No. 14.

April	10.0	2.59	60	11	.141 2.9	.082 1.6	41.9 34.8	5,400	950	82.4
May	17.0	2.57	59	8	.153 3.1	.074 1.7	51.6 45.2	3,900	120	96.9
June	23.5	2.66	27	2	.115 3.2	.063 1.2	45.2 45.5	850	34	96.0
July	26.5	2.55	67	3	.143 2.6	.068 1.4	52.4 46.2	2,200	41	98.1
August	26.5	2.27	147	17	.189 3.8	.090 1.9	52.3 50.0	3,000	110	96.3
September	24.0	2.54	26	8	.144 3.3	.091 2.0	36.7 39.5	1,300	50	96.2

Filter No. 15.

April	10.0	2.59	60	14	.141 2.9	.088 1.8	37.6 28.0	5,400	750	86.1
May	17.0	2.55	59	9	.153 3.1	.078 1.8	49.0 42.0	3,900	100	97.4

CHAPTER V.

Discussion of the Leading Factors associated with Efficiency and Cost of Operation of the English Filters receiving Plain Subsided Water, based on the Results of these Experiments.

The evidence presented in this chapter, dealing with the questions of the applicability and the most favorable conditions of English filters to purify satisfactorily the local river water after plain subsidence for two to three days, is arranged with reference to the separate consideration of five points, as follows:

I. The appearance of the effluent.

II. The removal of organic matter by the filters.

III. The bacterial efficiency of the filters.

IV. The cost of construction and of operation of the filters.

V. Resumé with an outline of conditions favoring the most efficient and at the same time the most economical filtration by this method.

The practical significance of a number of factors upon the above points in turn is discussed, the evidence being taken from the tables forming the last part of the preceding chapter. These factors, which for the most part are common to each

of the points of discussion, are given here for the sake of explicitness, as follows:

1. The composition of the applied water.
2. The effective size of the sand grains in the filter.
3. The thickness of the sand layer.
4. The rate of filtration.
5. The washing of the original sand before the construction of the sand layer.
6. The increases in losses of head during operation.
7. The scraping of the surface of the sand layer.
8. The abnormal disturbances of the surface.
9. The age of the filter.
10. The influence of nitrification of organic matter.

I.—ON THE PRACTICAL SIGNIFICANCE OF LEADING FACTORS WITH REGARD TO THE APPEARANCE OF THE EFFLUENT OF ENGLISH FILTERS.

The above stated factors are taken up in turn in this connection, which relates solely to the appearance of the effluent, due to suspended clay. With regard to dissolved color in this water, our observations show that when the suspended matters were completely removed from the water there was no dissolved color, practically speaking; although in precise terms the color averaged about 0.12 under such conditions.

The Composition of the Applied Water.

It is obvious that it is the clay in the applied water which is of importance in connection with the appearance of the effluent; and it is well to recall from foregoing chapters the statements relative to the great variations in the character and amount of suspended clay in the water going on to the filters.

When the applied water contained approximately 10 parts per million or less of suspended clay the effluent was clear, but it was not brilliant as the upper limit of this range of clay was reached. As this amount of clay, roughly, increased from 10 to 20 parts, the effluent was no longer clear, but contained a very slight turbidity, noticeable in vessels of clear, white glass. Under some conditions the turbidity of the effluent increased very rapidly, while in other cases a similar turbidity or appearance of the effluent were not reached until the suspended clay in the applied water approximated 50 parts. It is in the vicinity of this amount of suspended clay in the applied water where the dividing line came in the effluent with reference to its being satisfactory or not in appearance. This question of locating the limit in the suspended clay in the applied water, which will admit uniformly of an effluent of satisfactory appearance, is a matter of much importance, and is discussed beyond as a separate topic (page 180).

After a limit of about 50 parts of suspended clay was reached, and such water continued going on to the filters for a number of days, the turbidity of the effluents became decided. This turbidity of the effluents became more and more pronounced as the amount of suspended clay applied to the filters increased, and the application of turbid water continued for some days, until the effluents had a yellowish or brownish color, and resembled to a greater or less degree the unfiltered water. To produce an effluent so turbid that it was brownish in appearance, it was found that there was necessary a continuance for several days of the application of a water containing in the neighborhood of 150 to 200 parts per million of suspended clay. After the effluent became brownish in appearance it continued to be such for some days, with a smaller amount of applied clay than stated above.

Limit in Turbidity of a Satisfactory Effluent.

In the case of effluents which range in appearance at different times from perfect clearness (relative brilliancy) to the turbid brownish condition of the unfiltered water, it is necessary to place a limit upon the turbidity possessed by an effluent which would be thoroughly satisfactory to the water consumers. Obviously such a limit must be an arbitrary one. It is also a very difficult matter to decide upon this limit, because, on the one hand, the citizens have a right to insist that a purification plant, expensive even at a normal rated capacity, shall also be a clarification plant; while, on the other hand, small quantities of suspended clay appear in no way to be prejudicial to health, and at times of heavy rises in the river a plant capable of clarifying completely the water by this method would be expensive to a degree which would be impracticable.

The limit of turbidity in effluents of satisfactory appearance, which is used uniformly in this report, is practically the same as that used in the Louisville investigations. As was stated in the explanation of the tables at the close of Chapter IV (page 158), a series of standards containing known weights of very fine clay particles was used in obtaining the amount of clay present in the effluents. The limit of clay in satisfactory effluents was placed at six parts per million, as judged by these standards. This limit also separates degrees of clearness Nos. 3 and 4, such as was used at Louisville and in some places beyond in this report.

Efforts have been made to find some simple and fairly comprehensive way of expressing this limit independent of analytical methods. Owing to the variations in the character and appearance of these submicroscopic clay particles, and the great difficulty with which they can be separated in the

laboratory from the dissolved constituents of the water, it is almost impossible to locate this limit in simple terms. In fact, the same turbidity does not always correspond to the same number of parts of clay, according to the clay standards, due to differences in the color of the clay particles; and, accordingly, the clay standards are not perfectly satisfactory, although they served their purpose better than any other procedure which occurred to us.

In general terms it may be stated that the dividing line in the turbidities of effluents, rated as satisfactory and unsatisfactory in appearance, was such that, in glass vessels of thin white walls, agate type would be barely readable through a column of the water about 8 inches deep. The vanishing point of a platinum wire 0.012 inch in diameter in this water with a clear light would be at about 36 inches.

Limit in Turbidity of Applied Water yielding a Satisfactory Effluent.

The question of locating the amount of suspended clay (turbidity) of the subsided water, which under normal conditions of filtration would allow an effluent of satisfactory appearance to be obtained, is one of great importance from a practical point of view in connection with the problem at hand. Viewed in precise terms, there would be required for its solution many more data than we have available, owing to complications with other factors. Among these associated factors are the size and character of the suspended clay particles, the conditions of the construction and regular operation of the filters, the storage of clay within the filter, and the duration of the application of any given amount of clay. For the present it is sufficient to call attention to these

several factors, and illustrate their significance by the varying percentages of removal of clay by filter No. 13, the filter which was longest in operation, as follows:

Month.	Average Parts per Million of Suspended Clay.		Percentage Removal.
	Applied Subsided Water.	Effluent.	
1898 - April	60	9	85
May	59	5	92
June	27	2	93
July	67	2	97
August	147	12	92
September	21	3	86
October	22	1	95
November	59	8	86
December	72	10	86
1899—January	117	13	89

Notwithstanding the elements of variability, as shown above, it is believed that the amount of clay which English filters can remove satisfactorily may be stated, practically speaking, in fairly adequate terms.

Early in July a preliminary review of the first three months of operation of these filters was presented to you, and in it was a provisional estimate of the limit in question. It was found that on an average the collective data from all the filters showed that an effluent satisfactory in appearance was obtained with as high as 40 parts of clay in the applied water; and that the effluents were unsatisfactory in appearance when the applied clay averaged about 60 parts per million for several days in succession. From this evidence it was concluded provisionally that about 50 parts per million of suspended clay in the applied water was substantially the limit in amount

which could be regularly applied to English filters and obtain a satisfactory effluent in appearance.

It was pointed out in July that at the beginning of a rise, when the clay particles were somewhat coarser than at the end of a rise, and when the storage or retentive capacity of the sand layer is greatest, satisfactory results for a few days could be secured with 70 parts and more of applied clay. Recognition was also had of the fact that at that time no experience had been had with the turbid water of freshets of long duration.

Experience during the long August rise showed that the retentive or storage capacity of filters with thick sand layers and low rates was somewhat greater than was indicated by the results with the shorter preceding rises; that the range in character and fineness of the suspended clay in the subsided water was greater than the earlier evidence indicated to be the case; and that, due to the capacity of the sand layer to store clay, the period of very turbid effluents extended materially beyond the period of turbid applied water. It was also learned that the retentive capacity of filters with thick sand layers and low rates, within the limits studied, was incapable of producing satisfactory effluents during such long rises.

Although the evidence became rather modified after the preliminary review of the work in July, nevertheless the provisional estimate of 50 parts as the average maximum amount of permissible clay in the applied water was held to during the balance of the work, both with regard to operation of the filters and to the discussion of current results. While it is true that, for filters with sand layers five feet or more in thickness, and operated at rates of 1.5 million gallons per acre daily or less, this limit is too low, it is also true that such filters would not be uniformly successful, and accordingly the

limit is given for filters which would give most economical as well as satisfactory results except during long freshets.

Upon taking into consideration all of the evidence at the close of the work, it is finally concluded that the maximum permissible amount of clay in the water applied day after day to English filters under the local conditions ranges from about 30 to 70 and averages between 40 and 50 parts per million. The upper limit of this range was permissible during fairly short rises in the river and during the early part of long rises, while the lower limit was required during the latter part of long rises. For very short rises the capacity of the sand layer to store clay permitted the application of much more than 70 parts with satisfactory appearance of the effluent.

The Effective Size of the Sand Grains.

The available evidence shows that the fine sand employed in the tests was slightly but distinctly more efficient in removing clay from the applied water than was the medium sand, and the medium sand was correspondingly superior to the coarse sand. This is brought out by the following records of the average amount of clay from all comparable sets of daily observations for the months of April and May, when all of the filters were in operation, and of the percentage of the time when the effluents were satisfactory in appearance.

Summary of Results—April and May, 1898.

	Kind of Sand.		
	Fine.	Medium.	Coarse.
Effective size in millimeters	0.21	0.27	0.34
Average parts of clay in effluent	9	11	14
Average percentage removal of clay	85	82	77
Percentage of the time when the effluent was satisfactory	49	44	37

As filters continue in service it is well known that in a measure they behave like filters containing new but materially finer sand. The indications, from the operation of a number of these filters for six months, are that this was true here, but the data indicate a continuance of substantially the same relative efficiencies as just presented. In support of this the following data, averages of daily observations from three sets of fine and medium sand filters, are presented:

Summary of Results—June, July, and August, 1898.

	Kind of Sand.	
	Fine.	Medium.
Effective size in millimeters	0.21	0.27
Average parts of clay in effluent	8	10
Average percentage removal of clay	91	88
Percentage of the time when the effluent was satisfactory	62	53

The Thickness of the Sand Layer.

Within the limits in conditions and in thickness employed, 1, 3, and 5 feet, it was found that the thick layers were far superior to the medium and thin layers during the ordinary range in turbidity of the applied water; but when the turbidity of the applied water became great for quite a period the differences largely disappeared. The differences between the medium and thin layers corresponded somewhat with those between the thick and medium, but were distinctly less marked, all things considered.

It developed that the thick layers had a much greater capacity to hold back the clay particles than the medium and thin layers during rises; and, due to this fact, the thick layers gave, in several instances of short rises, satisfactory effluents

where the thinner layers failed. This was also true of the first part of long rises, but in these filters the several layers reached a basis of approximate equality toward the end of long rises.

By virtue of this greater retentive capacity of the thick layers, it was found that their superiority over thinner layers was far more marked when judged by the percentage of the time when the effluent was satisfactory in appearance than by the average parts of suspended clay in the effluent. This is natural, of course, because when the parts of suspended clay in the effluents are high the significance of difference in thickness of sand layer is eliminated. These conditions of affairs are made clearer by the following summaries, in which it is to be remembered that in August the applied water was very turbid.

Summary of Results.

Thickness of layer (feet)	5	3	1
APRIL AND MAY, 1898—			
Average parts of clay in effluent	9	11	15
Average percentage removal	85	82	75
Percentage of the time when the effluent was satisfactory	55	39	28
JUNE, 1898—			
Average parts of clay in effluent	2	3	4
Average percentage removal	93	89	85
Percentage of the time when the effluent was satisfactory	95	92	78
JULY, 1898—			
Average parts of clay in effluent	3	6	10
Average percentage removal	96	91	85
Percentage of the time when the effluent was satisfactory	95	82	31
*AUGUST, 1898—			
Average parts of clay in effluent	15	20	22
Average percentage removal	90	87	86
Percentage of the time when the effluent was satisfactory	16	0	0

* A portion of these data is estimated, as the filters were shut down before the close of the month.

The Rate of Filtration.

There seemed to be a slight but distinct advantage with the lower of the rates of filtration employed, 1.5, 2.6, and 4.0 million gallons per acre daily, and the difference between the low and medium was more marked than between the medium and high rate. The data obtained from the averages of all daily observations during April and May are as follows:

Summary of Results—April and May, 1898.

Rate of filtration	1.5	2.6	4.0
Average parts of clay in effluent	10	11	12
Average percentage removal	83	82	80
Percentage of the time when the effluent was satisfactory.	54	39	37

The low-rate filters were stopped before the heavy rise in August had been experimented with; but it was clear that the low rate, carrying less clay upon the sand layer, caused the retentive capacity of the sand to be overtaxed much less quickly than with higher rates. In this respect the low-rate filters behaved similarly to those with thick sand layers. However, the low rate of filtration at times of very turbid applied water was unable to yield an effluent which was not brownish and unsatisfactory in appearance. This was substantiated by experiences in August by reducing the rate of filtration of filters Nos. 7, 8, 13, and 14 to 1.5 million gallons per acre daily for a number of days.

In connection with the consideration of the influence of the rate of filtration upon the appearance of the effluent it is to be stated, in passing, that unequal rates of filtration at the same time through different parts of the sand layer are disturbing factors in the efficiency of a filter; and, in general terms, proof of this is not lacking in the data at hand.

The Washing of the Original Sand before Construction.

The original filters were constructed of unwashed sand pumped from the Dayton bar, as stated in Chapter II (page 59), and contained the following amounts of attached clay:

Coarse sand.....	2,300	parts per	million	of attached clay.
Medium sand	2,100	"	"	"
Fine sand.....	2,900	"	"	"

Owing to the fact that when the original filters were started the applied water contained more clay than it is possible to remove by this method of filtration, and also to the fact that no comparative data with washed sand were obtained, there is no precise information showing the degree to which the attached clay would affect the turbidity of the effluent if the filters were first started with unwashed sand and received applied water capable of being clarified. From general information, however, there is little room for doubt but that under normal conditions of procedure the attached clay of the sand layer from the Dayton bar would exert a well-defined influence upon the appearance of the effluent.

In August it was decided to learn more definitely the advisability of washing the sand before charging the filters with it, and also to investigate the question of securing satisfactory sand from bars above the mouth of the Little Miami River and near the new intake at California, where the purification works will be located.

The result of the investigation into the most suitable and accessible source of sand to be used in a large plant showed that at the sand bars opposite Coney Island, about 1.25 miles above the new intake, a sand of suitable size could be secured which has the advantage over the sand from the Dayton bar in that it is more uniform in size as it lies in place, and there-

fore cheaper to obtain by pumping. Furthermore, it is nearer to the site of the new works, and is above the immediate sources of sewage pollution.

Upon washing the Coney Island sand by an ejector washing machine, it was found that, practically speaking, none of the attached clay could be removed. In fact, the original sand from this source contained only 900 parts per million of attached clay, while the Dayton sand contained 1,100 parts after washing.

During the latter part of August there were constructed two filters, Nos. 18 and 19, in the tanks formerly occupied by filters Nos. 10 and 11, which were exact duplicates, except the sand in filter No. 19 was washed before it was put in place, while the other filter was charged with sand as it was pumped from the river at the Coney Island bar. The effective size of the sand was 0.22 millimeter; the thickness of sand layer 30 inches; and the rate of filtration 2.6 million gallons per acre daily.

These two filters were operated under precisely the same conditions during the first two weeks in September. In this time the clay in the applied water ranged from 66 to 4 and averaged 25 parts per million.

It was found that the effluents of these filters became satisfactory in appearance after five days' operation, and practically clear after ten days' operation. Viewing the data in precise terms, the advantage lay very slightly in favor of the filter containing the unwashed sand. Apparently the reason of this was that there were more films of organic matter around the sand grains, serving to increase the adhesiveness of the sand and the clay in the water.

From this experience it was concluded that, so far as the appearance of the effluent was concerned, it would be unnec-

essary in the construction of a municipal filter plant to go to the expense of washing sand obtained from the Coney Island bar.

The Increases in Loss of Head during Operation.

It would seem logical to suppose that, when the accumulations at and near the surface of the sand layer were such as to cause a marked increase over the initial loss of head which the water met in its passage through a filter, the efficiency of the filter would be increased in its power to remove clay from the subsided water. Furthermore, one might suppose that this condition of things would be a considerable factor at times when there was a sudden and marked increase in the turbidity of the applied water.

Careful inspection of all the records, however, shows that there was only an inconstant tendency in this direction, and no well-defined rule in harmony with these views. In fact, when the subsided water was such that it could be handled by these filters the loss of head was not a factor at all.

In connection with the explanation of these results, it may be noted that the increased losses of head occur at times when the retentive capacity of the sand layer is more or less exhausted; and, upon the application of very turbid water, the applied clay passes through the portion of the filter where the frictional resistance is greatest. It seems likely that somewhere between the conditions of non-accumulation (after scraping) and of overtaxed retentive capacity of the upper portion of a sand layer there might be a point where the efficiency of a filter would be greatest in the removal of turbidity. If such a point exists, and has any practical significance whatever, we were unable to obtain any definite information regarding it.

The records of operation in Chapter IV show that in a number of instances during the heavy August rise some of the filters were stopped and scraped when the loss of head reached 2 feet, or one half of the normal maximum loss of head. This was done with a view to guarding against unnecessary clogging of the lower portions of the sand layers, and to assist in obtaining an effluent of satisfactory appearance. In reference to the latter there is no evidence to indicate that the procedure was successful.

The Scraping of the Surface of the Sand Layer.

When the turbidity of the applied water was such that there could be obtained under normal conditions of filtration an effluent satisfactory in appearance, there were no indications whatever that surface scraping was a factor in this connection.

But when the amount of clay in the applied water was high there were several instances in which a slight beneficial influence upon the appearance of the effluent was exerted by surface scraping. There were also several cases where this factor appeared to produce a rather deteriorating effect. Regarding an explanation of these contradictory results at times of very turbid applied water, it is to be remembered that there are a number of associated factors to be considered in this connection. Among them are notably the character of the clay in the applied water, the penetration and storage of clay particles within the sand layer, with reference to the limit of storage power of the sand, and also the thickness and character of the portion of the sand layer removed by the particular scraping in question. The available evidence, however, upon the significance of these and perhaps other factors is too indefinite to admit of further consideration here.

Abnormal Disturbances of the Surface.

Disturbances of the surface of the sand layer of a filter cause the water to pass through the filter in channels, and consequently produce unequal rates of filtration. As has been stated already, these unequal rates of filtration produce a deteriorating effect upon the effluent, the effect in a measure being proportional to the inequality of the rates, as judged by the normal.

In these experimental filters the surface dirturbances, caused by fishes, earthworms, and the escape of inclosed air, covered a comparatively large proportion of the surface of the sand layer. Combining this fact with the small size of the filters, and the small difference in distance between any points on the surface and the exit into the effluent pipe, the opportunities for unequal rates of filtration following disturbances were abnormally small; consequently the deteriorating influence upon the appearance of the effluent of these filters, due to surface disturbances, was almost inappreciable.

The effect in practice of surface disturbances caused by the factors met with here, however, would undoubtedly be a serious matter, owing to the chances for unequal rates of filtration. This view is supported by the experiences in December, when partial freezing in the underdrains caused unequal rates in filters Nos. 13 and 16 (see page 175).

The Age of the Filter.

In considering the relation between the age of the filter and the appearance of the effluent, it will be advantageous to take it up separately with such applied water (normal) as can

be handled satisfactorily by this type of filtration, and also with subsided water of very high turbidity.

"*Normal*" *Applied Water.* — With filters constructed of such sand as may be pumped from the Coney Island bar, it was found that, with this character of applied water, the effluent would become reasonably satisfactory in five days and practically clear in ten days of normal operation. From this time on there is no evidence to indicate that the age of the filter would become a marked factor until the sand layer became so thin that it would be necessary to add more sand. It is true that the storage capacity of the sand for clay particles would be largely reduced at times, but the stored clay would be gradually washed out to a large degree during the fairly clear applied water which occurs between rises in the river.

On the other hand, a beneficial effect from age would arise from the increased adhesiveness of the sand grains. The practical significance of this was illustrated by the fact that filters Nos. 16 and 17, constructed of sand scraped from clogged surfaces and then washed, gave satisfactory effluents from the beginning, while Nos. 18 and 19, made of new sand, required five days, as stated above. In passing, it may be noted that the applied water in the case of Nos. 16 and 17 was rather more conducive to good work than in the case of the other pair of filters.

So far as we know now there would be no unsatisfactory results following the use of either new sand or washed sand to restore a sand layer to its original thickness, provided the old layer did not become too thin (less than about one foot), and sufficient care was taken to guard against clogging at the junction of the old and new sand.

Very Turbid Applied Water. — Were this type of water applied to filters constantly, the age of the filter would not be a factor, because the effluent would be constantly unsatisfactory. But when such a water is applied to filters at times of rises in the river the new filter is at a disadvantage, because the adhesiveness of its sand grains is abnormally low; and, further, the very old filter would be handicapped by its small margin in capacity to store clay. Somewhere between these extremes the optimum age of a filter would come; but, as stated above, the subject is too much complicated by other matters to enter into, even were it a matter of practical value.

The Nitrification of Organic Matter.

There is no evidence whatever to indicate that this was a factor (in connection with films of organic matter around the sand grains) in reference to the appearance of the effluent, for the reason that practically no nitrification occurred normally in these filters.

II. — ON THE PRACTICAL SIGNIFICANCE OF LEADING FACTORS WITH REGARD TO THE REMOVAL OF ORGANIC MATTER BY THE FILTERS.

At the beginning of this section it is necessary to state that from a hygienic standpoint the removal of organic matter from the Ohio River water at Cincinnati does not seem to be an important consideration, practically speaking. The reasons of this are that the organic matter for the most part is of vegetable origin and very stable in its character; when present in large amounts it is principally in suspension and not in

solution; with a purification process adequate to yield an effluent satisfactory with regard to appearance and removal of bacteria, the removal of organic matter is bound to be properly taken care of; and, finally, were all of the organic matter present in the effluent, the experience of the water consumers of this city for many years indicates that there would be exerted no well-defined influence prejudicial to health, under normal conditions.

However, for the sake of completeness, the practical significance of the more important factors of filtration are taken up in brief terms.

The Composition of the Applied Water.

The composition of the applied water affects the percentage removal of organic matter very materially, due to the wide variations in the total amounts present in it, and to the fact that the dissolved organic matter, which alone is present in clear effluents, is fairly constant, practically speaking, in the river water.

Concerning the remaining amount of organic matter in the water after filtration, the applied water is not a marked factor up to the point where its composition allows of complete clarification by this type of filter, although variations in the stability of the organic matter may have some significance. But when the applied water has such a composition that the effluents are turbid, then the point in question becomes a factor, because in turbid effluents suspended organic matter is present in amounts more or less proportional to the turbidity of the effluent, due to clay particles.

That the larger amounts of organic matter present in effluents are coincident with greater turbidities is illustrated by the

averages of all results for the month of July, as given in the next table. In studying this table it will be recalled that July was the fourth month during which these filters had been in continuous operation. For convenience the averages are arranged progressively with reference to the turbidity, as shown by the amount of suspended clay.

Monthly Averages for July, 1898.

Effluent of Filter Number	Parts per Million.		
	Suspended Clay.	Nitrogen as Albuminoid Ammonia.	Oxygen Consumed.
13	2	.063	1.3
10	3	.066	1.3
14	3	.068	1.4
11	3	.069	1.4
7	5	.070	1.4
8	7	.075	1.5
4	7	.078	1.5
5	8	.078	1.5
2	9	.082	1.6
1	11	.085	1.7
Subsided water...	67	.143	2.6

In part, but by no means wholly, the above differences in organic matter were caused by different capacities of the several filters to remove dissolved organic matter from the applied water.

The significance of the last-mentioned point is illustrated by the average results in the next table for the period June 17 to 25, inclusive. In this period all the effluents were uniformly clear, practically speaking; and the organic matter in the effluents was substantially all in solution. The results are

arranged progressively, according to the amount of organic matter contained in the effluents.

Averages for June 17–25, 1898.

Effluent of Filter Number	Parts per Million.		
	Suspended Clay.	Nitrogen as Albuminoid Ammonia.	Oxygen Consumed.
13	1	.053	0.8
10	1	.059	0.9
14	1	.057	1.0
7	1	.058	1.0
11	1	.059	1.0
8	1	.059	1.0
4	1	.059	1.1
1	1	.059	1.1
5	1	.060	1.1
2	1	.063	1.3

The Leading Features in the Construction and Operation of the Filters.

When the applied water was so turbid that the effluents were not clear, the removal of organic matter followed the same general line as the removal of clay; and reference is here made to the foregoing section, dealing with that subject. In the case of clear effluents there was a small margin of difference in the capacity of the several filters to remove dissolved organic matter, as indicated by the data in the last table. A brief summary of these differences is as follows:

1. Fine sand was slightly more efficient than medium sand; and from general information it is clear that medium sand was a little superior to coarse sand.

2. Appreciable advantages of medium layers were noted as compared with thin layers, and of thick layers as compared with medium ones.

3. The slower the rate of filtration the better were the results within very narrow limits.

Whether or not the chemical composition of the sand grains, part of them or all of them, was a factor in this connection, could not be determined from the available evidence.

On an average, the nitrogen as free ammonia in the effluents was 0.019 part, or 25 per cent less than in the river water.

Nitrification.

In these experimental filters conditions favorable to nitrification were present with reference to the amount of organic matter, dissolved oxygen, and temperature of the applied water; the necessary specific organisms of nitrification; and the manner of operation of the filters.

Notwithstanding this and the fact that every effort was made to detect slight evidences of nitrification of the organic matter stored within the filter, it was found that practically no nitrification took place. This is brought out in the next table, where all the evidence is summarized. As a rule, the effluents contained no nitrogen as nitrite.

The explanation of this practical absence of nitrification appears clearly to be the stable character of the organic matter in the applied water. It is a fact that nitrification did take place to a limited degree, as was shown by tests made during the summer of the effluents of filters which had been stopped for several weeks. The rate at which the process was carried on under normal conditions of practice, however, was so slow that it can be omitted from all consideration.

Monthly Averages of the Amount of Nitrogen in the Form of Nitrates.

Month—1898.	Parts per Million.	
	River Water.	Effluents of all Filters.
March	0.93	0.81
April	0.80	0.78
May	0.66	0.67
June	0.52	0.54
July	0.52	0.56
August	0.55	0.56
September	0.46	0.50
October	0.48	0.48
November	0.84	0.81
December	0.98	0.86

Within the limits of accuracy of the determination (about 0.04 part) it is seen that there is no substantial evidence of nitrification, although there was more or less of a tendency in that direction during warm weather. In explanation of the decreases in nitrates in the effluents, as indicated above, it is to be stated that during the first few weeks of operation there appeared to be some absorption of nitrates by the sand, as noted in filters elsewhere; and in December, when the river water varied in its contents of nitrates, the results were not in all cases representative of corresponding samples of river water and effluent.

III.—ON THE PRACTICAL SIGNIFICANCE OF LEADING FACTORS WITH REGARD TO THE BACTERIAL EFFICIENCY OF THE FILTERS.

The Composition of the Applied Water.

The evidence shows that the composition of the applied water exerted an influence upon the bacterial efficiency of the

filters by virtue of the variations in the numbers of applied bacteria.

It was seldom that the effluents contained fewer bacteria on an average than about 15 to 20 per cubic centimeter. On those occasions, such as occurred during the latter part of June, when the applied water contained only from 100 to 200 bacteria per cubic centimeter, the bacterial efficiency was normally only from 80 to 90.

As the applied bacteria increased in numbers up to the neighborhood of 15,000 per cubic centimeter, there was no corresponding increment in the bacteria in the effluent, although the numbers ordinarily were somewhat higher, but less than 100 per cubic centimeter. Consequently the bacterial efficiency under these conditions increased rapidly, and ranged for weeks at a time from 99 to 99.5 and above.

During the few short periods when the applied water contained bacteria in excess of 15,000 per cubic centimeter, it was found that the bacteria in the effluent ranged from about 100 to 200 and sometimes more, and, while the bacterial efficiency was high, it was less than when the applied bacteria were fewer.

Indirectly the composition of the applied water affected the bacterial efficiency of the filters when it contained more clay than the filters could handle properly. That is to say, when the applied water was such that the effluents were very turbid and had in a measure the brownish appearance of the applied water, then the bacteria in the effluents were high in numbers to an unusual degree. How it was that the bacteria under such conditions passed through the filters is not clearly known. But the practical significance of these conditions is shown by the following tabulations, containing, respectively, the average numbers of bacteria in the effluents and the bacterial efficiency

of the several filters during the week August 13 to 19, 1898. During this period all of the effluents were very turbid, containing from 25 to 30 parts of suspended clay and having a brownish appearance.

Average Daily Numbers of Bacteria per Cubic Centimeter, August 13–19, 1898.

Date—1898.	Sub-sided Water.	Effluents of Filters—Numbers.							
		1	4	5	7	8	9	13	14
August 13.....	4,800	.....	60	130	55	110	.....	19	50
August 14.....	6,100	4,100	85	200	44	180	180	40	325
August 15.....	3,200	750	.....	150	.....	130	170	60	130
August 16.....	2,300	450	90	325	75	95	190	75	110
August 17.. ...	3,100	280	110	170	110	140	230	85	130
August 18.....	1,600	275	110	150	100	100	200	60	170
August 19.....	1,700	240	140	85	85	80	100	60	110

Average Daily Bacterial Efficiency, August 13–19, 1898.

Date—1898.	Filters—Numbers.							
	1	4	5	7	8	9	13	14
August 13.....	.....	98.8	97.3	98.9	97.7	.....	99.6	99.0
August 14.....	82.8	98.6	96.7	99.3	87.0	95.1	99.3	94.7
August 15.....	76.6	.....	95.3	.....	95.9	94.7	98.1	95.9
August 16.....	80.4	96.1	85.9	96.8	95.9	91.7	96.7	95.2
August 17.....	91.0	96.4	94.5	96.4	95.5	92.6	97.3	95.8
August 18.....	82.8	93.1	90.6	93.8	93.8	87.5	96.2	89.4
August 19.....	85.9	91.8	95.0	95.0	95.3	94.1	96.5	93.5

This week, August 13 to 19, represents the most turbid water of the August rise. Were such a type of water to continue for a month or more, as would probably be the case during heavy winter freshets, there is no doubt but that the

deterioration in bacterial efficiency due to the cause under consideration would be more pronounced. In support of this see the high numbers of bacteria in the effluent of filter No. 13 in December and January (page 175).

In this section it is the comparative efficiencies which are dealt with, and not the absolute efficiency from a hygienic standpoint, as is considered in Section V. Nevertheless, it is believed that even for present purposes it is necessary to consider not only the bacterial efficiencies, but also the remaining numbers of bacteria in the effluents. Combining the two lines of evidence, it appears that the comparative evidence is more comprehensive when dealing with an applied water as variable as the one at hand.

The Effective Size of the Sand Grains.

In the following table are presented averages by months of the entire comparative data upon this point.

Summary of Bacterial Results from Filters of Different Sizes of Sand.

		Kind of Sand.			Subsided Water.
		Fine.	Medium.	Coarse.	
Effective size in millimeters		0.21	0.27	0.34	.....
Bacteria per cubic centimeter	April	800	850	800	5,400
	May	100	120	120	3,900
	June	30	45	.....	850
	July	32	47	.....	2,200
	August	60	100	.....	3,000
Bacterial efficiency	April	85.2	84.3	85.2	.....
	May	97.4	96.9	96.9	.....
	June	96.5	94.7	.....	.....
	July	98.5	97.9	.....	.....
	August	98.0	96.7	.....	.....

It is seen that on an average there was very little or no difference arising from the size of the sand grains during the first two months of operation. Then the fine sand filters showed a slight but distinct superiority over the medium ones, and from careful studies of the detailed data, including those from the coarse sand filter No. 9 during August, it is clear that the medium sand was correspondingly more effective than the coarse.

Had these filters continued in service under normal and practicable conditions, they would all probably have increased more or less in bacterial efficiency, but from general information it is believed that this efficiency would not become equal before it would be necessary to reconstruct the sand layers with new or washed sand.

The Thickness of the Sand Layer.

The evidence on an average shows that after the filters got into normal condition the thick layers were a little more efficient than the medium layers, and the medium slightly superior to the thin layers. These differences, however, were ordinarily very small, practically speaking, and became almost ***nil*** at times when the applied water was fairly clear or excessively turbid. During fairly short periods of marked turbidity in the subsided water the thicker layers were unquestionably an advantage.

In the table on the next page are presented monthly averages of the available comparable data :

Summary of Bacterial Results from Different Thicknesses of Sand Layer.

		Thickness of Sand Layer. Feet.			Subsided Water.
		5	3	1	
Bacteria per cubic centimeter	April	800	700	750	5,400
	May	110	110	130	3,900
	June	27	43	34	850
	July	30	43	70	2,200
	August	70	70	90	3,000
Bacterial efficiency	April	85.2	87.0	86.1	.....
	May	97.2	97.2	96.7	.....
	June	96.8	94.9	96.0	.....
	July	98.6	98.0	96.8	.....
	August	97.7	97.7	97.0	.....

Concerning the minimum thickness to which it is allowable to scrape filters and still secure satisfactory bacterial efficiency, it may be stated it does not appear wise to scrape them to less than about one foot, although it is true that under normal conditions this thickness does not seem to be imperative, but when abnormal conditions arise shallower layers are less safe.

The Rate of Filtration.

According to the average data presented on the next page, there was no well-marked advantage of low or medium rates over high rates. In fact, within the limits studied, the effect of the rate of filtration was practically *nil* upon the bacterial efficiency of filters under reasonably normal conditions.

Summary of Bacterial Results with Different Rates of Filtration.

		Rate of Filtration in Million Gallons per Acre, Daily.			Subsided Water.
		1.5	2.6	4.0	
Bacteria per cubic centimeter	April	950	750	750	5,400
	May	120	110	101	3,900
	June	39	43	40	850
	July	80*	43	45	2,200
	August	.....	70	85	3,000
Bacterial efficiency	April	82.4	86.1	86.1	.....
	May	96.9	97.2	97.4	.....
	June	95.4	94.9	95.3	.....
	July	96.4	98.1	98.0	.....
	August	.....	97.7	97.2	.....

* Abnormally high, due to surface disturbances in filter No. 11.

The above data and conclusions refer to rates which were substantially uniform and regular, except in the case of filter No. 11, as stated. With irregular rates of filtration, no matter how low may be the average rate, there is such a strong likelihood of obtaining a diminished bacterial efficiency, at least at times, that this condition is inadmissible in good practice.

The significance of irregular rates of filtration was demonstrated in the case of filter No. 13 on December 8 and 9, when accumulations of ice in the gravel underdrains beneath the sand caused marked irregularities in the rates of flow of the water through the filter. In the following table are presented the number of bacteria per cubic centimeter in the applied water

and in the effluent during the days mentioned and during the two preceding ones:

Date—1898.	Bacteria per Cubic Centimeter.	
	Applied Water.	Effluent of No. 13.
December 6	3 600	38
December 7	2,500	29
December 8	30,400	275
December 9	70,700	1,600

In a measure the higher number of bacteria in the effluent were due of course to the larger numbers in the applied water. But it appears that the irregular rates caused the numbers to be at least double what they otherwise would have been.

The Washing of the Original Sand Layer before Construction.

Filters of this type when new attain their normal bacterial efficiency in the shortest time when the sand grains contain few bacteria which can be mechanically detached by the flow of water, when the applied water is not excessively turbid, and when the conditions are favorable to the prompt formation of organic films around the sand grains to arrest the applied bacteria.

In these experimental filters when first placed in operation, the conditions with regard to the first two of the above-mentioned factors were very unfavorable. Concerning the third factor, the information is indefinite.

As pumped from the Dayton bar, the three grades of sand used in these filters contained many bacteria attached to the grains, as shown by the following results of analysis:

Coarse sand	440,000	bacteria per gram.
Medium sand	290,000	" "
Fine sand	183,000	" "

There is no doubt but that during the first and second week of operation the high numbers of bacteria in all of the effluents came largely from the sand grains; but during the next two weeks it seemed clear that they were associated chiefly with the turbid condition of the applied water. Had the applied water been of a character which could be handled properly by this type of filter, there are good reasons for believing that, even with unwashed sand from the Dayton bar, fairly good bacterial efficiency would be obtained from filters which had been in operation for about two weeks. Owing to the fact that for the first few days, when the bacteria are high in the effluent of filters made of unwashed sand, the filtered water would be largely mixed with unfiltered water in the piping system, it seems very questionable whether it would be advisable to wash the Dayton sand before using it for the construction of filters.

Further evidence along this line was obtained in September from the operation of filters Nos. 18 and 19, as described briefly in the discussion of this topic on page 188. These filters were duplicates made of Coney Island sand, except in one case the sand was washed before it was put into the filters, while in the other the sand was unwashed.

During the first two days of operation the bacteria in the effluent of the filter with unwashed sand were more than ten times as high as in the other effluent, and they continued rather higher for about five days. Beginning at about the end of the first week the filter with unwashed sand showed regularly a higher bacterial efficiency, apparently due to the adhesive action of films around the sand grains, and which in the other filter were more or less removed by washing. The applied water during this time was such as could be properly handled by these filters. At the end of two weeks when the

filters were stopped the one with a washed sand layer had not attained the bacterial efficiency shown by its mate.

From this evidence it is concluded that it would be unnecessary, if not inadvisable, to wash the sand pumped from the Coney Island bar (the most available source) before using it for the construction of filters.

In passing it may be stated here that clogged sand scraped from the surface of filters, *after washing*, gave a satisfactory bacterial efficiency with no very high numbers of bacteria in the effluent, much sooner than new river sand, either washed or unwashed.

The Increases in Loss of Head during Operation.

Eliminating from present consideration the question of the immediate effect of scraping, the evidence shows in practical terms that there was no substantial differences in bacterial efficiency with different losses of head. It is true that in some instances there seemed to be well-defined tendencies towards improved results as the loss of head increased, but these tendencies were never pronounced. If this tendency approached one of the regular laws of filtration under the existing conditions, there were one or more other factors which were capable of disguising it completely, or very nearly so. In fact, there were many instances where the bacterial efficiency diminished as the loss of head increased.

The above inferences refer solely to positive heads. Negative heads (or those in excess of the depth of water above the sand) were impracticable under the existing conditions for a number of reasons, among which were tendencies to irregular rates of filtration with their resultant diminution in bacterial efficiency.

The Scraping of the Surface of the Sand Layer.

At the outset it is to be stated that the importance of this point was clearly recognized from the first, and a careful procedure for operating the filters at such times as described on page 132 was uniformly followed to keep its effect upon the bacterial efficiency as small as practicable. The evidence upon this subject, as shown by the results of special bacterial analyses on each occasion, was given in full in the tables beginning on page 166. The averages of all these results for each filter, together with the total average of all results, are presented in the following table:

Summary of Bacterial Results to show the Effect of Scraping.

Bacteria per Cubic Centimeter.

Number of Filter.	Number of Scrapings.	Average Results of Regular Samples on Preceding Days.		Special Results after Passage of Stated Quantities of Effluent in Million Gallons per Acre after Scraping.								Average Results of Regular Samples.		
												Day of Scraping.	Day after Scraping.	
		Second.	First.	.15	.27	.39	.51	.63	.87	1.20	Ave.		First.	Second.
1.....	4	70	65	170	160	170	160	140	170	140	160	140	180	120
2	3	85	100	180	160	200	300	170	275	140	190	210	210	120
3.....	1	120	130	150	200	200	200	95	95	80	150	190	160	130
4.....	9	65	60	190	120	110	250	100	170	140	160	160	130	85
5.....	5	70	85	100	140	160	350	170	180	160	170	140	160	130
6.....	1	140	220	210	210	200	250	275	180	230	220	225	170	90
7.....	7	60	50	70	95	120	140	85	110	95	100	85	90	60
8.....	4	60	90	120	160	170	180	160	160	210	170	180	150	100
9.	2	120	150	110	150	140	120	130	95	130	120	130	120	100
10	3	80	60	80	80	90	100	120	110	120	100	80	110	60
11.....	2	110	140	180	120	200	110	180	180	800	250	300	800	300
12.....	1	250	120	160	110	95	110	110	90	70	110	125	160	110
13.....	11	70	190	70	110	120	220	140	140	190	140	110	80	90
14	4	70	90	75	85	95	90	100	75	65	80	85	120	75
15	1	95	140	200	200	180	240	210	200	170	200	190	120	75
Average	58	100	110	140	140	150	190	150	150	180	150	160	180	120

In the comparison of the relative total average numbers of bacteria present in the effluent at different times with reference to surface scraping, it is seen that the averages in the preceding table show the relative numbers expressed in percentages of those present on the second day preceding scraping.

To make these data more comprehensive there should be taken into consideration the numbers of bacteria in the applied water. The total average numbers of bacteria in the applied water during each day in question for each filter were as follows:

Bacteria per Cubic Centimeter in Applied Water.

Number of Filter.	Days preceding Scraping.		Days of Scraping.	Days after Scraping.	
	Second.	First.		First.	Second.
1	4,900	3,400	4,800	4,000	4,400
2	2,700	3,300	2,000	2,400	1,700
3	6,200	3,300	2,100	2,900	1,900
4	3,700	4,600	3,800	3,500	3,000
5	2,400	3,600	2,700	3,200	2,200
6	8,900	4,500	6,200	3,300	2,100
7	4,800	3,100	2,200	1,700	1,200
8	3,100	2,800	2,300	3,300	3,600
9	6,200	3,300	1,400	1,900	1,100
10	5,900	3,800	4,100	2,700	4,300
11	5,600	2,400	1,800	2,100	3,000
12	4,000	4,500	3,000	2,000	2,600
13	7,700	10,600	6,800	5,100	3,800
14	3,700	2,200	2,000	3,500	3,400
15	4,500	6,200	3,300	2,100	2,900
Average	5,000	4,100	3,200	2,900	2,800

It is seen from the above data that on an average the effect of scraping, as practiced here with great effort to avoid disturbances in the main body of the sand layer during refilling, upon the bacterial efficiency of the filters, was to cause a slight but clearly appreciable diminution. Viewed from the standpoint of the number of bacteria remaining in the effluent, the influence of scraping was more pronounced. But when it is considered that in practice not more than ten per cent of the surface of the filters would be scraped at a time, the dilution, by the effluent of the remaining ninety per cent of the plant, of the effluent from the recently scraped portions would cause the increases in the numbers of bacteria, as recorded above, to be hardly appreciable, practically speaking.

In order to look into the relation between the effect of scraping and the leading factors in the construction and operation of the filters, an arbitrary classification of the scraping data has been adopted as follows:

Class A means that scraping produced no appreciable effect upon the bacterial efficiency of the filters.

Class B means that there was a distinct increase in the numbers of bacteria in the effluent, but that the latter seldom, if ever, exceeded 100 per cubic centimeter. When the filters were new this class included those marked increases which did not exceed the normal more than 100 per cubic centimeter.

Class C means that the bacterial increases were marked and exceeded the above mentioned limit.

Classification of Scraping Data for each Filter on the above Basis.

Number of Filter.	Classification.			Number of Scrapings.
	A.	B.	C.	
1	0	1	3	4
2	0	1	2	3
3	0	1	0	1
4	2	3	4	9
5	0	3	2	5
6	0	1	0	1
7	1	4	2	7
8	0	2	2	4
9	1	0	1	2
10	1	2	0	3
11	0	1	1	2
12	1	0	0	1
13	7	4	0	11
14	0	4	0	4
15	0	1	0	1
Totals	13	28	17	58

So far as the available evidence goes, there are no clear indications of a well-marked relation, under normal and satisfactory conditions of operation, between the effect of scraping and the size of the sand grains, the thickness of the sand layer, or the rate of filtration. When the filters were new they were all somewhat less efficient just after scraping. After they had once attained their normal efficiency, diminutions in efficiency at times of scraping were ordinarily associated with excessive turbidity of the applied water or with disturbances of the surface, principally the latter.

If filters were allowed to have the sand layers reduced by successive scrapings to much less than one foot in thickness, the probabilities of undiminished bacterial efficiency directly after scraping would become less certain; but, with filters in normal condition, there appeared to be no substantial differences in efficiencies at times of scraping between filters having one and five feet of sand.

With regard to the effect upon the bacterial efficiency of those special procedures (consisting of scraping at a two-foot loss of head, allowing the applied water above the sand to settle over night, and reducing the rate for a day or so) tried in August in a number of instances, the evidence shows nothing definite. In fact, from inspection of the bacterial data alone it is impossible to tell at what scrapings these special procedures were practiced.

Considering the results of the total 58 scrapings on the basis described in connection with the last table, the classification may be summarized as follows:

Class A	13
Class B	28
Class C	17
Total	58

In studying these results it is to be remembered that a fair proportion of them was obtained when the filters were new, and when there were abnormal conditions, such as surface disturbances and excessive turbidity of the applied water, for weeks at a time, which are not permissible in good practice with this type of filtration. But, notwithstanding these facts, the effect of scraping in 71 per cent of the cases (Classes A and B) was so slight that it would scarcely be appreciated by the water consumer; and the dilution of the effluent of the scraped filter

by the remainder of the filtered water in the case of Class C would reduce the deteriorating effect of scraping to a point which could hardly be regarded as serious, from a practical standpoint.

On the whole, it is concluded that these data are sufficiently satisfactory to render it inadvisable to adopt more expensive and time-consuming methods in operating the filters at times of scraping.

Abnormal Disturbances of the Surface.

While these experimental filters were so small that the deteriorating influence of surface disturbances, producing irregular rates of filtration, was somewhat lessened, yet it was quite pronounced in several cases. This is shown by the following results obtained from filters Nos. 2 and 11 early in July, when there were marked cases of surface disturbance in these filters:

Date—1898.	Bacteria per Cubic Centimeter in Applied Water.	Filter No. 2.		Filter No. 11.	
		Loss of Head. — Feet.	Bacteria per Cubic Centimeter in Effluent.	Loss of Head. — Feet.	Bacteria per Cubic Centimeter in Effluent.
Average, June 24–30	1,600	....	44	....	43
July 1	1,200	1.3	160	0.5	38
July 2.....	2,100	1.6	300	0.5	65
July 3.....	1,500	1.4	250	0.4	110
July 4.....	1,200	1.1	140	0.4	205
July 5.. ...	1,500	0.8	110	0.8	170
July 6.....	2,500	1.0	100	0.4	110
July 7.....	3,200	0.9	60	0.3	60

In large filters the deteriorating effect of surface disturbances would probably be much greater; and it is clear that within practical limits every effort should be made to have this factor absent in practice.

Age of the Filter.

It required between one and two months for these experimental filters to attain normal bacterial efficiency. This was due largely to the very turbid condition of the applied water, and had the filters been put in service early in January, before the winter rise came, it is believed that they would not have been in good condition before May, four months afterwards, and perhaps later.

Judging from experiences with filters Nos. 16, 17, 18, and 19, about two weeks of operation are necessary to attain satisfactory bacterial efficiency, under normal conditions, with regard to the sand layer and the character of the applied water applicable to this type of filtration.

As filters grow old there is a tendency toward improved bacterial efficiency, but it is doubtful whether it could be regarded as of practical significance.

When sand layers are restored to their original thickness by the addition of thoroughly washed sand which had previously been removed from the clogged surface of the filters, there is no evidence to show that the bacterial efficiency would be affected upon resuming operation.

Nitrification of Organic Matter.

So far as could be learned, nitrification was not a factor in the bacterial efficiency of these filters.

I.—ON THE PRACTICAL SIGNIFICANCE OF LEADING FACTORS WITH REGARD TO THE COST OF CONSTRUCTION AND OF OPERATION OF THE FILTERS.

It is the purpose in this section to show the relative significance of the principal elements of the cost of filtration, with regard to those conditions conducive to most efficient clarification and purification. For the sake of explicitness the several elements are dealt with individually for the most part at this point; and in a subsequent portion of the report the actual collective cost of filtration in connection with preliminary treatment by subsidence, etc., is considered.

As appears from the above title, there are two sides to the question of cost of filtration—namely, that of construction and of operation. With regard to the former, which is considered first, we shall refer only to those features of construction that are distinctively related to the efficiency of filtration, and pass by those points which are of importance only from a purely constructive point of view.

Concerning the cost of operation, the comparable data are fewer and less complete than at first thought would be expected from the range and duration of the investigations, owing to a variety of more or less obscuring complications. For these reasons this portion of the discussion is somewhat brief, especially as it is the object to bring out the important facts and tendencies from a practical standpoint rather than to deduce the abstract laws of filtration.

THE ELEMENTS OF COST IN THE CONSTRUCTION OF FILTERS.

The principal points in this connection, which in most instances were actually met with during these investigations, are taken up in turn, as follows:

The Filter Basins.

Relative to the size of the individual basins, and the style of construction of the bottoms and sides of the basins, there are no comments to be made here; and it only requires the statement that the bottom of the basins should be water-tight, and that effective means should be adopted to guard against the passage of unfiltered water between the sides of the basin and the sand layer, and thence through the underdrains to the exit conduits.

Exit Conduits and Underdrains.

From available data these portions of a filter may be designed in a satisfactory manner. It is worthy of mention, however, that arrangements should be such that the rate of filtration be as uniform as practicable at all points on the sand layer, and that the sand and gravel should be perfectly supported, practically speaking, by the respective underlying layers. In these experimental filters, about 12 feet in diameter, the underdrains were about 4 inches thick and made of five layers of graded material, as described on page 55. When these materials were removed after the filters were stopped it was found that, while the underdrains served their purpose satisfactorily, there was a noticeable settling of the gravel down into the next lower layer, especially in the case of the pea gravel, which was not very uniform in size.

Under the conditions of practice these layers would have to be much thicker, and the evidence indicates that three carefully selected grades of stone and gravel of sufficient thickness would serve their purpose.

Kind of Sand.

Experience showed that the fine sand pumped from the sand bars in the river in the vicinity of Coney Island, without further washing, is the most efficient and economical of the local materials available for the construction of filters of this type.

Placement of the Sand.

It is necessary in putting the sand in place in the filters to avoid dropping it from some distance, and also any other procedures which would tend to admit of unlike degrees of compactness of the sand layer.

Thickness of the Sand Layer.

While it is true that, under the condition with reference to turbidity of the applied water which existed at times during the test of the original filters, the five-foot layers were more efficient than the three-foot sand layers; yet, when the applied water was such that it could be regularly clarified and purified by these filters, there was no substantial difference in efficiency of the three-foot and of the five-foot sand layers. In the light of this evidence, and from the fact that the three-foot layers would be materially cheaper to construct, and would allow of successive scrapings for a year with a sufficient remaining layer, it is concluded that in practice it would be best to construct filters with sand layers three feet in thickness.

Depth of Water above the Sand.

The depth of water in these filters was four feet above the original sand surface. During operation, of course, this depth increased, due to the settlement of the sand (about 10 per cent of the thickness) and to the removal of sand by scraping.

From the evidence at hand it does not seem advisable to provide for a less depth than this (the limit of available positive head); and it is very questionable whether there would be any corresponding advantage to offset the increased cost of provisions for greater depths of water.

Actual Rate of Filtration.

Obviously the rate at which the water passes through the filter is an important factor relative to the cost of filtration, because it controls, in a large measure, the area of filters which it is necessary to provide in order to obtain a given quantity of filtered water. All things taken into consideration, there was nothing in the qualitative efficiency of the low and medium rates of filtration employed in the operation of these filters, 1.5 and 2.6 million gallons per acre daily, to compensate for the cost of providing for the additional area of filters to maintain such rates, as compared with the high rate of 4 million gallons per acre daily. For this reason it is concluded that the 4-million gallon rate would be the best to adopt in practice.

When the applied water was of such a turbidity that this type of filter would regularly clarify and purify it, the above conclusion is perfectly true, practically speaking. But there were conditions of applied water continuing for short periods only, as discussed earlier in this chapter, when the low rate was most efficient. The significance of this, however, is small when the entire problem is viewed in a comprehensive manner.

Relation between the Actual and Net Rates of Filtration.

Owing to the fact that filters of this type are out of service from time to time to allow the surface of the sand layer to be scraped to relieve clogging, the net capacity of these filters for

a given period falls appreciably below that indicated by the actual rate of filtration. It is customary in designing filters of this type to provide a reserve area of filters of about 20 per cent in order to compensate for differences between the actual rated capacity and the net capacity of the plant under the least favorable conditions.

Under normal conditions this difference is greatest when scraping is most frequent and accomplished under the most time-consuming conditions. Barring out for the present the question of excessively turbid applied water, this difference would be greatest under local conditions during winter weather when the viscosity (and friction) of the water is greatest, and freezing interferes with scraping to a great or less degree.

Mr. Hazen has proposed the rule that when the mean January temperature of a locality is not below freezing, then it is unnecessary to provide covers for these filters. On this basis covers would not be needed for filters at Cincinnati, although the margin is a narrow one. Actual experience in operating the experimental filters here, however, shows that it is quite likely that trouble would be encountered during the winter in scraping open filters so that the net capacity of a filter would come within 20 per cent of the rated capacity.

It has occurred to us that a better basis of studying the relation between temperature and probable difficulties with freezing at times of required scraping is to consider the frequency and duration of periods when the mean daily temperature was 23 degrees Fahrenheit or less. This temperature was selected because it is about as cold as experience shows that the uncovered filters will stand during scraping without serious freezing of the moist sand. The data upon this for the last ten years at Cincinnati are as follows:

Table showing the Frequency and Duration at Cincinnati, Ohio, of Periods of "Cold" Weather (mean daily temperature of 23 degrees Fahrenheit or less) and Intervening Periods of "Warm" Weather (above the stated limit) expressed in Days for the last Ten Winters.

	Weather during Winter.									
	1888–89	1889–90	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98
Cold	2	1	1	2	1	1	3	3	4	1
Warm...	4	1	37	10	7	44	1	7	21	4
Cold	2	1	1	1	1	1	2	1	1	2
Warm...	5	35	24	35	3	1	2	20	12	7
Cold	2	2	1	1	17	1	1	3	1	2
Warm...	2	3	2	3	14	20	7	26	16	29
Cold	2	1	1	1	1	3	3	1	8	3
Warm...	.....	.....	9	1	2	8	9	5	26	.....
Cold	.....	....	1	2	2	1	1	1	2	.....
Warm...	.....	.....	.....	3	11	9	2	11	.....	.....
Cold	.....	.....	.....	3	1	2	5	3	.....	.....
Warm...	.....	.....	.....	2	30	4	1	.....	.....	.....
Cold	.....	.....	.....	3	1	1	1	.....	.....	.....
Warm...	.....	.....	.....	.....	.....	.....	1	.....	.....	.....
Cold	.....	.....	.....	.....	.....	.....	12	.....	.....	.....

These data indicate that, independent of the great turbidity of the water at times of heavy winter freshets, there would be occasions when delays of a number of days would arise before filters could be properly scraped. In extreme cases of continued cold, furthermore, it seems very possible, if not probable, that the normal yield of filtered water could not be maintained with open filters without comparatively large reserve areas of filters. What percentage the reserve area should form of that normally

required can not be definitely determined in the absence of specific information; but it seems probable that the area of the filters should be from 30 to 50 per cent larger than would be required, were complications from freezing weather eliminated.

In passing, it may be noted that reductions in the net capacity of filters, due to the frequency of scraping, caused by algæ growths, are not a matter of consideration here, because the turbidity of the applied water excludes sunlight to a degree which practically prevents the growths of such micro-organisms.

Covers for the Filters.

As noted above, covers for the filters would not be needed here to prevent growths of algæ and other minute organisms.

The complications associated with the scraping of the filters during cold winter weather could be largely obviated by covers for the filters. As the cost of the filters would be increased approximately 50 per cent by covering the filters, the proposition becomes one of deciding whether it is cheaper to cover the filters normally required, or to provide a large reserve area of filters to overcome difficulties during freezing weather. It is to be remembered in this connection that the topography of the ground and the available land near the new works are not favorable to the expansion of a filter plant of this type at a moderate cost.

Taking all things into consideration, it seems advisable, were this method of purification adopted, to construct filters with liberal provisions for the increased consumption of filtered water in the future, and omit both covers and large reserve areas for overcoming complications from freezing. Ultimately, however, in the opinion of the writer, it is likely that it would be found best to cover the filters rather than increase their area.

Appliances for Controlling the Flow of Water within the Filter Plant.

In view of the fact that it is imperative to maintain a uniform rate of filtration, great care should be taken with this object in view in arranging the piping system of the filters and the necessary appurtenances. So far as practicable, the flow of water, both at the inlet and outlet of each filter, should be controlled automatically.

Another point of importance is that provisions should be made for filling filters after scraping from below with filtered water obtained from other filters. It is very essential during this filling that the flow of water should be well under control, and with the requirement of as little attention as automatic devices will allow.

Sand-washing Device.

Although there is an abundance of suitable new sand in the sand bars in the river near the new works, there is no room for doubt but that economy demands that, for restoring the sand layers from time to time to their original thickness, the clogged sand removed by scraping should be washed and replaced, rather than use new sand for this purpose.

There are several types of sand-washing devices which have been used for this purpose with greater or less success. Of these types we have regarded most favorably the ejector type of sand washer.

A small sand washer of this type was constructed and used at the experimental plant with satisfactory results. As a matter of record the leading features of its construction are given in Plate XII. It was found that the clogged material removed from filters of coarse, medium, and fine sand required different

volumes of water for satisfactory washing. On an average, one volume of clogged coarse, medium, and fine sand required, respectively, 15, 20, and 25 volumes of water. The pressure of the water at each nozzle was ten pounds, approximately.

So far as our observations went, it is not necessary to use filtered water for sand washing, although when the river water is in its most turbid condition it would be more or less undesirable for this purpose, both before and after subsidence.

The arrangement and location of the sand washers, and provisions for the transportion of the sand from the filters to the washers and back again, as well as for the storage of the sand for a year or so between replacements, are matters requiring consideration. In these investigations no points of importance were learned except the above-stated volumes of required water, and the general observation that in practice three men ought to attend to a machine having a capacity of about four cubic yards of sand per hour.

Elements of Cost in the Operation of Filters.

Clearly enough, the principal elements of cost in the operation of a filter plant are as follows:

1. That of scraping the surface of the filters from time to time, as required, in order to relieve clogging, and the restoration of the sand layers to their original thickness once a year or so.

2. That of supervision and attendance of the normal operation of the filters.

The second of these elements is not a great one, relatively speaking, because the filter plant itself, independent of the preliminary treatment necessary to prepare the river water satisfactorily for filtration, could be properly operated by one person skilled in this line of work, with the assistance of one

trained analyst and of several intelligent laborers to operate valves and read gages. The cost of this is considered beyond, and needs no discussion here.

Relative to the first of the above-mentioned factors of cost of operation, it is one of the principal items of cost of filtration by this method, and is discussed as fully as the evidence permits. Obviously there are two phases to the cost of scraping, namely:

A. The frequency of scraping.

B. The quantity of material removed by scraping and subsequently requiring to be washed and replaced.

For the sake of convenience the influence of leading factors upon each of the two phases of this subject is discussed separately, and the practical significance of the two, taken collectively, is considered in the resumé (Section V). The detailed data were presented in the tables beginning on page 160.

A.—ON THE INFLUENCE OF LEADING FACTORS UPON THE FREQUENCY OF SCRAPING.

Already it has been shown that the frequency of scraping is a factor in the cost of construction of filters, because it determines largely the required reserve area of filters; consequently it influences the cost of operation through the fixed charge for interest. It also affects the cost of operation, for the reason that frequent shallow scrapings are more expensive than deeper scrapings to the same total depth, but at less frequent intervals.

The frequency of scraping is denoted in these discussions by the volume of water filtered during the periods between scrapings. From this the frequency in days can be readily obtained, according to the rate of filtration employed. Unless otherwise stated, these quantities represented periods which ended when the loss of head reached four feet.

Composition of the Applied Water.

In the case of the majority of waters filtered by this method the composition is so uniform, with the exception of occasional algæ growths, that the frequency of scraping does not vary to a marked degree, other conditions being equal. But with the very variable Ohio River water with respect to suspended matters this is not true, as appears from the following comparisons. Algæ growths, however, are not a local factor.

Unsubsided Ohio River Water.—At various times during the year, and aggregating about four months, the Ohio River water at Cincinnati, according to available evidence, could be successfully filtered without preliminary treatment of any kind, and the filters would probably keep within the customary limits of from 50 to 100 million gallons per acre between scrapings. On an average it appears that the yield would be in the vicinity of 60 million gallons under these conditions.

During the remaining portion of the year, aggregating about eight months, however, the large amounts of suspended matter in the river water would necessitate scraping with much greater frequency. In general terms it may be stated that, from observations in connection with filter No. 13 and others of a less specific nature, the periods between scrapings would range from 50 down to about 5 million gallons per acre. What the average would be during freshets can not be stated. But it is not a matter of consequence, owing to the utter impracticability of the lowest limits.

Subsided Water during Freshets.—Owing to the minuteness of the clay particles remaining in the subsided water, the frequency of scraping under the conditions stated was not found to be as great as would naturally be expected from the appearance of the applied water. By virtue of the passage of the clay

into and through the sand layer the yield per period repeatedly reached from 75 to 100 million gallons per acre. However, the evidence points to the fact that there would be many instances where more than from 20 to 30 million gallons per acre could not be depended upon.

Subsided Water in the absence of Freshets.—As follows from the statements relative to the river water without subsidence for about four months in the year, there would be no need of this preliminary treatment at these times; and on account of the inability of the fine suspended matter to concentrate itself immediately upon the surface of the sand layer, the periods would be long, relatively speaking. In general terms, the evidence indicates that the yield per period would range ordinarily from 50 to 100 and average about 75 million gallons per acre.

Temperature of the Applied Water.

The laws of hydraulics show that, due to greater viscosity, the water at winter temperature offers more than double the frictional resistance in its flow through sand than it does at summer temperature.

This fact was kept clearly in mind in studying the evidence, as it was thought that possibly it might affect the decision as to the most suitable fineness of sand and rate of filtration. But, so far as could be learned, its influence was not appreciable in the presence of other and more weighty factors; and, practically speaking, this matter does not seem to be one of serious moment.

CONSTRUCTION AND OPERATION OF THE FILTERS.

Under this heading are considered the following leading factors: The size of the sand grains; the thickness of the sand layer; and the rate of filtration.

Size of Sand.—Within the limits studied it was found that the fine sand required scraping, other conditions being equal, at somewhat more frequent intervals than did the medium sand; and in turn the medium required scraping more often than the coarse sand. The differences, however, were not very great, and were insufficient to mitigate against the fine sand. As the filters grew older the differences tended to lessen, and in time perhaps they would disappear in the case of these sands. In explanation of the difference noted it is to be stated that the finer sands had a somewhat greater power to retain the clay at and near the surface of the sand layer.

Thickness of Sand Layer.—So far as could be learned, the thickness of the sand layer was not a factor, under the conditions investigated, in regard to the frequency of scraping.

Rate of Filtration.—Obviously the high rates required more frequent scraping, when expressed in days per period, than the lower rates, because they carried clogging materials on to the filters more rapidly. But when the length of periods is expressed the quantity of water filtered, the low rates necessitating scraping at slightly more frequent intervals, evidently due to their somewhat greater ability to hold the applied clay near the surface of the sand layer.

Increases in the Loss of Head (Maximum Head before Scraping).

It is self-evident that the frequency of scraping, other things being equal, becomes less as the maximum loss of head increases. At the outset of this work it was decided to carry the loss of head to the maximum practicable limit; and, accordingly, the filters were constructed with an available acting head of about 13 feet. Of this, 4 feet were positive (above the plane of maximum resistance) and the remaining 9 feet were negative.

Experience showed in the case of every filter during the first period that it was not practicable to carry the loss of head in excess of the positive head or depth of water above the sand. The reason of this was that the diminution in pressure on the water after it left the section of greatest frictional resistance (at the sand surface) caused the release by the water of dissolved air, which accumulated in the pores of the sand layer to such an extent that of itself it became a marked factor in clogging.

This is shown by the following tabulation containing the average results obtained from all of the filters:

Percentage of the Effluent obtained for each Successive Foot of Acting Head up to 13 Feet.

	Foot of Head.						
	1	2	3	4	5	6	7-13 inclusive.
Percentage of total effluent	36	21	13	11	4	5	10

According to these data, 8 per cent of the total yield was obtained with the 4 feet of positive head, while the 9 feet of negative head furnished only 19 per cent of the total volume of effluent. In other words, the positive head yielded four times as much water as the negative head, and there was no corresponding compensation to offset the disadvantage and extra cost of providing the negative head.

On the whole, it is believed that these data are fairly representative of local conditions. The newness of the filters perhaps tended to exaggerate somewhat the disadvantage of negative heads; but, on the other hand, the reverse would be true during the winter when the temperature of the water would cause a greater and more rapid evolution of air.

Beginning about June 1, after each filter had been scraped once, the rule was adopted of scraping filters under normal conditions, when the loss of head reached 4 feet.

Disturbances on the surface of the sand layer, due to fishes, earthworms, etc., caused irregularities in the loss of head and in the rate of filtration, and therefore necessitated scraping at once. This condition of affairs repeatedly made the periods between scrapings abnormally short.

At times of heavy freshets some of the filters were scraped when the loss of head reached 2 feet. The object of this was to guard against complications from subsurface clogging, but it increased materially the frequency of scraping, as appears from the data in the last table.

Procedures at Times of Scraping.

The principal features for consideration in this connection are the thickness of material removed; the careful refilling of the filters from below with filtered water; the occasional sedimentation of the subsided water above the sand; and the reduction in the rate of filtration in putting a filter in operation after scraping it (with no wastage of filtered water).

Within practicable limits these factors were not found to be of great importance. Nevertheless, the thickness of the sand layer removed was probably somewhat of a factor in some instances, and the removal of air from the pores of the sand layer by filling from below doubtless tended to lessen the frequency of scraping, especially on those occasions when the applied water was saturated with air.

The Age of the Filter.

So far as our actual information goes, the age of the filter exerted far less influence upon the frequency of scraping than

would naturally be expected. This was due in part to the passage at times of freshets of a considerable percentage of the applied clay through the filter into the effluent, and in part to the storage of clay within the main body of the sand layer, where it would be gradually washed out in a large measure during the period of fairly clear applied water coming between freshets.

With the type of subsided water met with from April to December, inclusive, 1898, it is believed that, when scraping is carried out to restore the loss of head practically to the original, there would be a clearly recognized increase in the frequency of scraping, but that it would not become a matter of vital importance within the period of about one year, when the sand layers would in a measure be reconstructed. However, it is very likely that when winter freshets continued for several months this factor would become one of considerable concern. Just how much it would interfere with the operation of filters can not be told from the evidence at hand.

B.—ON THE INFLUENCE OF LEADING FACTORS UPON THE QUANTITY OF SAND REMOVED BY SCRAPING.

According to the best available evidence as to the experience abroad with this type of filter, there is ordinarily removed at each scraping from 0.5 to 0.75 inch, the average apparently being nearer the latter figure. The quantity of sand removed depends of course upon the frequency of scraping, and is best expressed for practical comparisons in cubic yards removed per million gallons of effluent. Ordinarily this quantity ranges from 1 to 2 cubic yards per million gallons, and apparently averages somewhat nearer the higher limit of this range. With clear lake waters and with waters highly charged with

algæ growths, the above figures decrease and increase, respectively.

With the Ohio River water at Cincinnati after two to three days' subsidence, the quantity of sand removed was found under actual conditions, with reference to excessive turbidity of the applied water and the disturbances of the surface of the sand layer, to become greater, and on a number of occasions reached 5.0 cubic yards or more per million gallons.

The data upon this subject presented in Table No. 1 of Chapter IV (see page 160) are complicated by a series of factors more or less unknown in many instances. For that reason it is not possible to discuss this topic in precise terms, but the following comments cover the leading points which were brought out during the work.

Composition of the Applied Water.

Actual data show that variations in the amount of suspended matter in the applied water are sufficient to cause the quantity of sand to be removed to increase from 1.5 to 3.0 cubic yards per million gallons of effluent. In all probability, at times of prolonged heavy freshets during the winter, the applied clay alone would make these figures as high as 5.0 cubic yards, and perhaps higher.

But taking every thing into consideration, the composition of the applied water is less of a factor than would be expected, as an increase of ten to twenty fold in the applied clay did not more than double the quantity of sand removed.

In fact, the evidence shows, with regard to the quantity of sand removed for the same amounts of applied clay and with substantially the same conditions of the sand layer after scraping, that on an average there was no marked difference in the case of these experimental filters. In this connection

reference is made to the data up to August 1, in Table No. 1 of Chapter IV (see page 160), upon the quantity of sand removed per ton of applied suspended matter per acre.

The Maximum Loss of Head.

According to the available evidence, it would increase the quantity of sand to be removed if the filters were scraped before the loss of head reached four feet. The increase, however, would not bear a direct relation to the percentage of the head used, because each successive foot of head corresponds to gradually decreasing yields of effluents; and, further, it is impracticable to scrape off less than a certain thickness of sand, in practice about 0.5 inch.

The use of negative heads apparently did not affect markedly the quantity of sand removed.

Disturbances of the Surface of the Sand Layer.

When disturbances of the surface of the sand, due to animal life, became so marked that it was necessary to scrape the filters, the quantity of sand removed was abnormally great.

As a matter of fact, the surface disturbances were one of the principal causes in making non-comparable our data obtained during the summer.

Procedures at Times of Scraping.

Of the several steps in the process of scraping described in Chapter IV (page 132), the thickness of the layer removed appears to be the only one affecting essentially the quantity of sand removed per million gallons of effluent filtered. During the first four months of operation of these filters it was the uniform custom to scrape the filters down to a well-defined plane, separating the discolored from the uncolored sand.

Gradually this plane of demarcation disappeared, owing to the deep penetration of the clay, and the discoloration extended in a gradually decreasing degree to a depth of six inches or more from the surface; consequently this method of scraping became impracticable.

Beginning in August, the custom was changed with respect to the thickness of the sand layer removed. Thereafter the filters were scraped so that the sand layer removed never exceeded about one inch in thickness, and when the appearance of the sand warranted it the thickness was less. By this procedure the loss of head in some instances was not restored to the original amount, but it was very nearly so, practically speaking, and the method seemed to be a success.

According to the evidence obtained after August 1, the indications were that, with the modified procedure with respect to the thickness of the sand layer removed, this factor was not of importance in the quantity of sand scraped from filters expressed in cubic yards per million gallons of effluent. In fact, the controlling elements seemed clearly to be the composition of the applied water and the maximum loss of head which was used.

The Age of the Filter.

With the Ohio River water at Cincinnati, after subsidence for two to three days, it is believed that as the filters continued in service the quantity of sand removed per million gallons of effluent would increase somewhat. This would be due to the accumulation of clay of considerable duration within the main body of the sand layer. During moderate rises in the river and during heavy freshets of short duration, the age of the filter would probably not be much of a factor, but during prolonged heavy freshets the present indications are that this factor would make its influence felt materially.

In this connection it is instructive to compare the results of the amounts of clay found to be attached to the sand at different depths in filters Nos. 4, 5, and 8, about the middle of August:

Depth from Surface.	Parts per Million of Clay.		
Inches.	Filter No. 4.	Filter No. 5.	Filter No. 8.
0—1	71,800	60,000	44,800
3	46,000		14,300
6	30,000	.....	6,300
7	.....	41,400	4,500
9	.....	15,700	3,500
12	.....	7,600	3,700
24	.....	5,400	2,500
Bottom	.....	5,100	3,600
Original sand.....	2,100	2,100	2,100

RESUMÉ AND CONCLUSIONS.

Expressed in brief terms, a resumé with conclusions as to the applicability and efficiency of the fifteen original filters of the English type in solving the local problem may be stated as follows:

Inapplicability of English Filters in the Clarification and Purification of the Unsubsided Ohio River Water at Cincinnati.

While it is true that for about four months in the year English filters are applicable for the clarification and purification of the unsubsided Ohio River water with satisfactory efficiency and at a reasonable cost, yet for the balance of the year the large amounts of suspended matter in the river water make these filters inapplicable in unqualified terms.

Inapplicability of English Filters in the Clarification and Purification of the Ohio River Water at Cincinnati after Plain Subsidence for about Three Days.

Experience in the operation of these experimental filters, under the conditions stated, showed that the preliminary treatment of subsidence for three days was insufficient to prepare the river water so that at all times it could be satisfactorily treated by these filters as constructed and operated. The situation with reference to the leading factors of practical significance may be reviewed as follows:

Clarification.

The evidence shows that the effluents would be satisfactory on an average for seven to eight months in the year; but for the remaining portions of the year, made up of the periods of freshets, the effluent would be markedly turbid and brownish at times, and as a rule it would be far from the clearness which the citizens would have a right to expect from a plant which would necessarily represent a considerable cost.

Bacterial Efficiency.

After the first two or three weeks of operation the filters showed a satisfactory bacterial efficiency so long as the applied water did not become excessively turbid for a fairly long period. Under the latter conditions, such as would arise during the long and heavy winter freshets, there are good reasons for believing that deterioration in the bacterial quality of the effluent would be quite a serious matter. (See page 175.)

While it is true that in the light of our present knowledge upon the science and art of water purification these filters ordi-

narily gave very satisfactory bacterial efficiencies (see monthly averages, pages 172 to 175), still it is not to be forgotten that they are not germ proof. In substantiation of this is the evidence upon the passage through the filters of *B. coli communis*, the leading fecal bacterium which was present quite regularly in the applied water. Weekly (or biweekly) tests were made for the presence of this germ in 50 cubic centimeters of each of the effluents. The results of these tests are summarized in the following table, where it is seen that in nearly half of the cases on an average this species of bacterium was found in the effluent.

Summary of the Results of Tests for the Presence of B. Coli Communis in the Several Effluents.

Effluent of Filter Number.	Number of Tests Made.	Percentage of Tests which gave Positive Results.
1	6	50
2	4	0
3	1	100
4	10	40
5	6	17
6	1	0
7	9	33
8	6	50
9	5	20
10	2	0
11	3	33
12	1	0
13	24	46
14	10	50
15	1	100

Removal of Organic Matter.

Independent of the organic matter associated with the turbidity of the effluents, the efficiency of the filters in this respect was satisfactory. Furthermore, it is very doubtful whether the organic matter suspended in the turbid effluents had any sanitary significance whatever, practically speaking.

Construction of Filters.

Underdrains.—The underdrains should support the sand layers completely, and should be arranged to allow equal rates of filtration through the entire area of the filter. In practice, the factor of safety with reference to supporting the sand layer should be greater than in these filters.

Kind and Size of Sand.—The most suitable available sand for local filters of this type is that which is pumped from the sand bars in the river opposite Coney Island. Its effective size averages 0.22 millimeter, and its uniformity coefficient is 1.5. There is no need of washing it before its placement in the filters.

Thickness of Sand Layer.—At times of freshets thick sand layers, by virtue of their greater capacity to store clay particles, are more efficient than thin layers. But 5-foot layers during long freshets were found to be inadequate. From a theoretical standpoint it seems probable that, with conventional rates of filtration, sand layers could be made sufficiently thick so as to yield a satisfactory effluent at all times. The available evidence, however, indicates that the cost of such a procedure would make it impracticable.

Under normal conditions—that is, at times when the effluent would be satisfactory in character—it was found that 3-foot layers were substantially as efficient as 5-foot layers.

Depth of Water.—The depth of water above the original sand surface, 4 feet, could not apparently be modified to advantage.

Reserve Area of Filters.—To maintain the normal yield of effluent during the winter freshets, it would apparently be necessary to double approximately the conventional (20 per cent) reserve limit of filter area.

Covers of Filters.—At the outset it does not seem advisable to cover the filters; but as the increased water consumption reduced the reserve area of filters, it is believed that it would be found better to cover the filters rather than increase the area, under the existing local conditions.

Applied Water Screens.—Screens should be arranged to remove from the applied water, so far as practicable, all fishes, earthworms, and other forms of animal life.

Regulating Devices.—The devices for regulating the flow of the influent and effluent water should be made as efficient and automatic as possible.

Sand-washing Plant.—Economy demands that a sand-washing machine with necessary appliances for moving the sand should be an adjunct of the filter plant. The ejector type of washer was used with satisfactory results.

Operation of the Filters.

Rate of Filtration.—Under favorable conditions with regard to the composition of the applied water, where it was possible to obtain a satisfactory effluent from these experimental filters, there was no marked difference in efficiency in the three rates tested—1.5, 2.6, and 4.0 million gallons per acre daily. From this evidence it is clear that under normal conditions a a rate of 4.0 million gallons per acre daily would be most advisable.

When the applied water contained large amounts of clay the low rate was most efficient, because the storage capacity of the sand layer was exhausted much less quickly than at higher rates. But a rate of 1.5 million gallons per acre daily would not carry satisfactorily a filter, with a sand layer five feet in thickness, through the long freshets.

Unquestionably it is possible to reduce the rate of filtration so that the subsided water could be satisfactorily clarified and purified at all times, but the cost would be clearly prohibitive.

Uniformity of Rate.—The rate of filtration should be practically uniform, and provisions should be made for regulating the operation of the filters to that end.

Maximum Loss of Head.—Experience showed that the loss of head ought not to be carried beyond the depth of the water above the sand layer. When the character of the effluent is satisfactory with regard to appearance, there is no reason why advantage can not be taken of the full positive head.

Procedure at Times of Scraping.—No serious diminution in the quality of the effluent followed the fixed procedure finally adopted, as follows: Drain the filter so that workmen can stand on the fairly dry sand layer; scrape off one inch or less; fill from below with filtered water at the regular rate until the water stands several inches deep upon the sand; turn on the applied water slowly at first so as not to disturb the sand surface; and when the basin is full begin filtration at once at the normal rate.

No appreciable advantages were noted from allowing the applied water above the sand to settle, nor from reducing the rate of filtration for a short period when resuming filtration. With ordinary care there was no need of wasting any of the effluent just after scraping.

Frequency of Scraping.—With this river water after about three days' subsidence, and with a rate of filtration of four million gallons per acre daily through a filter of fine sand, it is estimated that on an average there would be required, according to the above stated procedure, about twenty scrapings per year.

Quantity of Sand Removed.—Under the conditions stated above, it is estimated that the quantity of sand removed by scraping would average about 2.25 cubic yards per million gallons of effluent.

Reconstruction of Sand Layer.—In the case of filters originally having sand layers three feet in thickness, it is probable that they would have to be restored to their original thickness about once a year, certainly oftener than every two years. If special care were taken to guard against clogging at the junction of the old and new sand, it is believed that several years might elapse without having to take out all of the sand down to the gravel layers, and wash it before replacement.

Sand Washing.—The evidence shows that it could be cheaper and better to wash the sand removed by clogging rather than use new sand for maintaining the thickness of the sand layers. By the ejector type of sand washer it was found that the fine Coney Island sand, removed in a clogged condition by scraping, could be washed satisfactorily with twenty-five volumes of (fairly clear but unfiltered) water to one volume of sand.

Final Conclusions.

In the absence of heavy and long-continued freshets in the river, three days' subsidence would be adequate to allow the local water to be satisfactorily clarified and purified by this type of filter and at a reasonable cost. When heavy and

long-continued rises in the river do occur, the method under consideration would not be a success, with filters constructed within conventional limits as to thickness of sand layer and operated within conventional limits as to rate of filtration. Their failure under such conditions would be due to the excessive turbidity of the effluent; the diminution in bacterial efficiency toward the end of long rises; and to the abnormal expense of cleaning the sand layers.

It would be possible by increasing sufficiently the thickness of the sand layer, or by decreasing sufficiently the rate of filtration, or by a combination of these two modifications, to obtain uniformly an effluent of satisfactory character and appearance from the local river water after plain subsidence for three days. But the cost of such procedures would clearly make them prohibitive.

To make use successfully at all times of English filters it would be necessary at times of freshets to give to the Ohio River at Cincinnati further preparatory treatment than is afforded by three days of plain subsidence.

CHAPTER VI.

Description of the Operation of the Modified English System and a Summary of the Principal Results accomplished Therewith.

On July 6, 1898, a communication was addressed to you, in which it was recommended, after reviewing the results obtained from the operation of the original English filter from March 28 to June 30, inclusive, that modifications be made in the experimental plant. The object of these modifications was to test the practicability of provisions to secure at times of freshets in the river supplementary clarification of the river water following plain subsidence for about three days, and preceding filtration through filters of the English type.

For convenience this proposed method is called the *modified English system of purification.* Attention is especially called to the expression "system of purification," comprising plain subsidence, coagulation, and supplementary subsidence (when needed) and filtration. It is much more comprehensive than the conventional term filtration, and is much more correct under the conditions to be considered here.

Authority was granted by the Board of Trustees on July 27 to proceed with the modifications recommended. In addition to stopping permanently a number (7) of the original experimental filters, coagulating and supplementary subsiding basin

E and filters Nos. 16 and 17 were constructed, as described in Chapter II. (See pages 71 and 76.)

Before describing the results of the operation of these three new devices, the situation at the commencement of this portion of the investigations will be explained more fully.

PRINCIPLES UPON WHICH WERE BASED THE PROPOSED MODIFIED SYSTEM OF PURIFICATION.

The available evidence on July 1, based on the results of operation for three months of the original filters, showed that plain subsidence for about three days was insufficient to prepare the river water of average composition for successful and practicable clarification by the English type of filters; and during about half of this period these filters were a failure, practically speaking. Furthermore, the indications were that during the latter part of prolonged freshets in the river the results from the filters (constructed and operated within conventional and practicable limits) would be unsatisfactory in almost every respect.

Under these conditions the proposition of making satisfactory use of English filters in a system of purification for the local river water became, practically, one of further preparation by addional clarification of the turbid river water during freshets before its application to the filters. Of course this additional clarification could be obtained by plain subsidence for a longer period; but this procedure would be very expensive, because the fixed capital charges for interest and sinking fund would be constant, whereas the need of additional preparation beyond plain subsidence for about three days would be required in the course of a year, only about one third of the time in the aggregate. Economy demanded, therefore, that, if possible, means be secured whereby the necessary supplementary and intermediate treatment could be obtained at a

reasonable cost when actually used, and with only a very slight expense when at times of clear water in the river it would not be needed.

So far as our knowledge upon such matters went, this could best be done by applying a coagulating chemical in suitable quantities to the regularly subsided water, when excessive amounts of clay make it very turbid, and then allowing the coagulated clay to subside in a comparatively small basin before the water reached the filters. By a suitable amount of the coagulant is meant such a quantity as would cause the effluent of the coagulating basin to contain no more than an average amount of about 40 to 50 parts per million of suspended clay. From Chapter V (page 180) it will be recalled that this was the normal limit of clay in the applied water, which can be regularly and satisfactorily handled by English filters under normal conditions.

It will be seen at once that an important function of the coagulating basin was to remove almost completely the gelatinous precipitate formed by the applied chemical (coagulant), otherwise it would pass on to the filter, and clog the surface of the sand layer so rapidly that the procedure would be impracticable.

Relative to the particular coagulating chemical to be used, this is not a specification in the method. As a matter of fact, that chemical should be used which would accomplish the work at the least cost, and produce no objectionable change in the character of the water, practically speaking. At the present time apparently those conditions are best fulfilled by sulphate of alumina, and therefore this chemical was used during these tests. It is quite possible, however, as our knowledge of coagulating chemicals advances, that it might be found advantageous to substitute some other chemical for the one stated. If this

were done, it would apparently not involve any essential changes in the plant for this modified method.

The English filters themselves, both with regard to construction and operation, but independent of efficiency and economy, would not be affected by this modification in the system. In the two new experimental filters advantage was taken of the best and most practicable conditions, as represented by our experience with the fifteen original filters of this type.

OBJECTS OF THE EXPERIMENTAL INVESTIGATIONS WITH REGARD TO THE MODIFIED ENGLISH SYSTEM.

In brief terms, the principal objects of the tests described and discussed in this chapter may be outlined as follows:

1. To determine, so far as practicable, the most economical period to provide for the coagulation and supplementary subsidence of the plain subsided water after the application of the chemical to it and before its passage on to the filters.

2. To determine approximately the amount of chemical which would be required during freshets in the river to accomplish the coagulation needed for the supplementary clarification.

3. To learn the influence upon the efficiency and cost of operation of English filters of applied water containing at all times suspended clay only within the limits which the filters can handle, and also containing possibly at certain times a small amount of the gelatinous precipitate which failed to subside in the secondary subsiding basin.

KIND, COMPOSITION, AND BEHAVIOR OF THE CHEMICAL APPLIED TO THE PLAIN SUBSIDED WATER.

Kind.—Sulphate of alumina was used regularly in these tests, because it was considered to be the most applicable one,

all things considered. As stated previously, however, this particular chemical is not essential to this method, and there could be substituted for it any means of securing coagulation by a superior process.

Composition.—Four different lots of commercial sulphate of alumina were used, having the following composition, respectively:

Percentage Composition of Sulphate of Alumina.

	Number of Lot.			
	1	2	3	4
Matter insoluble in water	0.13	0.08	0.12	0.11
Available alumina (Al_2O_3)	17.56	16.72	17.70	18.17
Sulphuric acid (SO_3)	37.77	36.66	37.32	37.50
Water (H_2O)	44.54	46.54	44.86	44.22
Lime (CaO)	0.	0.	0.	0.
Oxide of iron (Fe_2O_3)	Trace	Trace	Trace	Trace

These analyses indicate moderately rich grades of sulphate of alumina. They were all basic, no free sulphuric acid being present in any instance.

The periods during which these respective lots of sulphate of alumina were used, when required, were as follows:

Lot No. 1 ..... Period—Aug. 8 to Nov. 4.
" 2 ..... " Nov. 4 to Dec. 7.
" 3 ..... " Dec. 13 to Jan. 11.
" 4 ..... " Jan. 11 to Jan. 25.

From December 7 to 13 a small lot of commercial alum crystals was used. This chemical contained about 10.70 per cent of available alumina, and was applied on the basis of equivalent strength to the sulphate of alumina.

Behavior.—The principal features in the behavior of this chemical when applied to turbid waters of this section are

well known from earlier reports, but for convenience are reviewed here briefly.

When sulphate of alumina is applied to the turbid water after plain subsidence, a small part of the chemical is generally absorbed by the suspended matters, but the remaining and greater part is decomposed by the alkaline compounds naturally dissolved in the river water. These alkaline compounds comprise the carbonates and bicarbonates of lime and magnesia.

In the decomposition of the applied chemical by the alkaline compounds of the water, the strong sulphuric acid of the sulphate of alumina displaces the weak carbonic acid of the alkaline compounds. The result of this is that there are formed the soluble sulphates of lime and magnesia, while an equivalent amount of carbonic acid is liberated in the form of a gas which, uniting with the water, forms free carbonic acid. The alumina of the applied chemical unites with water, and forms the white, insoluble and gelatinous hydrate of aluminum. It is this latter compound which actually accomplishes the coagulation of the clay.

Part of the gelatinous hydrate appears to be absorbed or attached to the clay particles without coagulating them; but, taken as a whole, it serves to aggregate the minute clay particles into fairly large masses, relatively speaking, which can be more readily removed by subsidence or filtration. This process of coagulation and aggregation of clay particles may be better understood by comparing it with the clarification of turbid coffee by the addition of white of eggs.

On account of the richness of the Ohio River water at this point in salts of lime and magnesia, there is no probability that, under reasonable conditions of practice, there would ever be needed more sulphate of alumina than could be completely

decomposed by the natural constituents of the water. This being true, the probabilities are very remote for complications popularly associated with the use of this chemical, and which would exist to a greater or less degree were the undecomposed chemical allowed to pass into the filtered water.

Under the existing conditions the advantages of this coagulating chemical may be secured through its decomposition, and the coagulation of the clay into masses including the aluminum hydrate, and these masses are readily removed, while the only changes in the water are that the soluble carbonates of lime and magnesia (alkalinity) are converted in equivalent amounts into the soluble sulphates of these bases (incrusting constituents), and there is liberated a small and proportional amount of free carbonic acid. The sulphates of lime and magnesia and the free carbonic acid are associated with incrustations in steam boilers and with the corrosion of uncoated iron, respectively. But, with the quantities of applied chemical required for the subsided water, the increases in the filtered water of these two constituents above the amounts naturally present there are quite insignificant, practically speaking. The sum of the alkalinity and the incrusting constituents, representing the total hardness and the soap-consuming power of the water, is not affected by the application of this chemical. In the following chapters the evidence supporting this view is entered into at greater length.

DESCRIPTION OF THE OPERATION OF COAGULATING AND SUBSIDING BASIN *E* AND A SUMMARY OF THE PRINCIPAL AVERAGE RESULTS THEREFROM.

Although the plain subsided water after leaving the steel tanks passed uniformly through basin E, without important exceptions, on its way to filters Nos. 16 and 17, from the

beginning of its use, August 8, yet chemical was applied only at times corresponding to freshets in the river. When the river water was fairly clear and no chemical was applied at basin E, the plain subsided water was changed in its composition only very slightly by its passage through this supplementary basin, and these nominal changes were not placed on record. This was considered unnecessary for the reason that the basin was a part of the system; and the data immediately associated with it were of value and importance only when the water applied to it was above the average limit of 40 to 50 parts per million of suspended clay, capable of being handled regularly by English filters under the given conditions.

Of necessity the coagulation and supplementary clarification of the water in basin E, practically speaking, took place only at irregular intervals, when the plain subsided water was turbid; and as a matter of convenience the description and records of its work are presented in periods.

Period No. 1.

Duration.—This period extended from August 8, when these devices were first placed in operation, until September 1, the end of the turbid water coming from the midsummer rise in the river. This corresponds to lots of subsided water Nos. 112 to 126, inclusive.

The Character of the Plain Subsided Water.—The subsided water during this period represented the latter part of a long-continued summer freshet. Analyses showed that the suspended clay ranged from 59 to 292 parts, and averaged 148 parts.

Taking every thing into consideration, the plain subsided water during this period was apparently more easy to handle

than the average water during freshets. That is to say, the subsided water at this time seemed to be coagulated with relatively less chemical, and subsided more readily than is normally the case, and the absence of extreme variations in quantities of clay made the control of the process easier than at other periods.

Period of Coagulation and Subsidence. — Basin E had a capacity of 10 hours' flow at the rate of which the water was passed through it. Actual observations showed that the average period of subsidence was substantially equal to the displacement period, but that some of the water passed through in about 4 hours.

Amount of Applied Chemical. — It was the purpose to apply chemical in such amounts that after about 10 hours of additional subsidence the water would contain practically 50 parts per million of suspended clay. Taking every thing into consideration, this purpose was fulfilled to a reasonably satisfactory degree. However, there were several instances where the amount of chemical was too low and others where it was too high. In the case of lot No. 117 the removal was abnormally low, due to an accidental interruption in the application of the chemical. The removal was too high in the case of lot No. 124, through a mistake in the rate of application of chemical. It seems quite possible that, with the last few lots, depositions of coagulated material in the bottom of the tank may have been stirred up by the flow of water and assisted a little in the clarification. This view is supported by the partial clarification which took place in basin E, in the case of lots Nos. 127 and 128, which received no chemical.

The range of applied chemical in grains per gallon was from 0.95 to 2.00, and the average was 1.47 grains. On the

whole it is believed from later experience that these quantities are materially lower than would be the case with corresponding weights of suspended clay during freshets of an average character, with respect to the nature of the clay particles.

Cleaning of the Basin.—Basin E was cleaned out on August 17 and again at the close of the period. The arrangements for draining the basin were such that the material which had to be cleaned out was very thin, and was easily swept out with a broom. In the time which elapsed between cleanings the deposited matters did not decompose to a degree where they became black and of a consistency like rubber.

Suspended Chemical in the Effluent of the Basin.—So far as we could learn, the effluent of basin E was practically free of suspended chemical (aluminum hydrate) as it passed upon filters Nos. 16 and 17. This belief was based upon observation of the sedimentation of the water in bottles, and also upon the normal increases in the loss of head as the water passed through the filters.

The effluent of basin E, however, was not absolutely free of suspended chemical, as was learned by inspecting the surfaces of the sand layers of filters Nos. 16 and 17, when they were drained for scraping.

Undecomposed Chemical in the Effluent.—A series of very careful and frequent analyses of the effluent showed, beyond any doubt, that none of the applied chemical passed through the system in an undecomposed form, and this was true uniformly throughout these tests.

Composition of the Clarified Water.—During this period analyses were made of each lot of water, as it left basin E on its way to filters Nos. 16 and 17, with respect to total organic matter (both nitrogenous and carbonaceous), and bac-

teria as well as suspended clay. The results of these analyses are given in the next table, which also shows the amount of chemical employed and the clarification which it effected.

As basin E is only an intermediate part of this system, and corresponding with no comparable portion in the original English filters, the analysis with regard to organic matter and bacteria in the effluent of this basin were omitted in subsequent periods. The efficiencies of filters Nos. 16 and 17 are based upon the composition of the plain subsided water (influent to basin E).

Summary of Average Results of Operation of Basin E by Lots—Period No. 1.

Number of Lot.	Grains per Gall. of Applied Chemical	Parts per Million.						Bacteria per Cubic Centimeter.	
		Susp. Matter.		Nitrog. Matter		Carb. Matter.			
		*Influent.	Effluent.	Influent.	Effluent.	Influent.	Effluent.	Influent.	Effluent.
112	0.95	176	51	.192	.124	3.3	2.6	3,500	2,8[illegible]
113	1.69	225	58	.202	.100	3.7	1.9	4,000	3,10[illegible]
114	1.85	292	67	.258	.101	4.9	2.2	4,000	3,6[illegible]
115	1.75	212	60	.216	.110	4.7	2.5	4,800	1,8[illegible]
116	1.92	248	40	.244	.106	5.3	2.5	2,700	1,0[illegible]
117	1.12	199	83	.210	.122	5.0	3.2	3,100	2,0[illegible]
118	2.00	122	35	.174	.114	3.8	2.8	1,600	7[illegible]
119	1.16	96	43	.190	.112	5.4	2.8	1,600	1,0[illegible]
120	1.30	150	42	.194	.104	4.5	2.3	6,200	1,8[illegible]
121	1.25	136	40	.210	.091	4.1	2.4	3,700	1,4[illegible]
122	1.38	124	55	.192	.122	4.4	2.8	4,200	6[illegible]
123	1.00	78	37	.154	.126	3.9	2.5	1,200	5[illegible]
124	1.60	59	33	.156	.114	3.5	2.8	1,500	4[illegible]
125	1.50	112	33	.166	.110	3.6	2.2	1,500	400
126	1.00	68	23	.178	.126	3.4	2.7	2,000	8[illegible]

* The influent of basin E was of course identical with the plain subsided water.

Period No. 2.

During the interval from September 26 to October 28, the arrangement of the baffle walls in basin E was modified so as to allow of the use of this tank in connection with filter No. 16, and obtain different periods of coagulation and sedimentation. Filter No. 16 was to be operated at rates of 4 and 5 million gallons per acre per day, and valves were placed on the outlet pipe from basin E so that 5.0 and 7.5 hours of average subsidence could be obtained at these rates. These modifications are described in detail in Chapter II, page 72.

Duration.—This period extended from October 28 to November 2, and for convenience in presentation it is also made to include the short period of use on November 4 and 5.

Character of the Plain Subsided Water.—This period started on a minor rise in the river during which the suspended matters in the plain subsided water ranged from 124 parts at the beginning of the period to 70 parts on November 1. On November 4 and 5 the suspended matters averaged about 50 parts. As judged by the removal of suspended matters by plain subsidence, there was nothing very abnormal about the character of the suspended matter in the river water during this period, and the matters remaining in the water after plain subsidence were probably mainly clay of a normal character, except that laboratory observations on November 4 and 5 indicated that the material was rather difficult to coagulate.

Period of Coagulation and Sedimentation.—From October 28 to October 31, and on November 4 and 5, the normal period of coagulation from sedimentation was 5.0 hours, and on October 31 and November 1 a period of 7.5 hours was used.

Cleaning of the Basin.—The basin was not cleaned during this period.

Character of the Clarified Water.—The effluent from basin E during this period was sufficiently clarified, so far as the suspended clay particles were concerned, to be readily handled by filters of the English type; but the rapidity with which the loss of head increased on filter No. 16 indicates that there was considerable coagulated material left in the effluent from this basin. This is clearly shown by the following table, in which the average weight of suspended matter passing on to filter No. 16, and the loss of head on this filter at 12 P. M. for each day of period No. 5 for this filter, are given:

Date—1898.	*Average Amount of Suspended Matter—Parts per Million.	Loss of Head at 12 P. M. Feet.
October 21	11	0.5
" 22	14	0.5
" 23	12	0.5
" 24	14	0.5
" 25	16	0.5
" 26	12	0.5
" 27	17	0.7
" 28	43	0.9
" 29	64	1.8
" 30	80	2.1
" 31	29	2.9
November 1	33	3.6
" 2	75	4.0

* Chemical was applied to basin E from October 28 to November 2 (inclusive).

The average results of operation of basin E during this period for the removal of suspended matters are given in the following table. As a matter of convenience the results are arranged by lots, but it is to be noted that only a portion of lot No. 168 was treated.

Summary of Average Results of Operation of Basin E by Lots — Period No. 2.

Number of Lot.	Grains per Gallon of Applied Chemical.	Suspended Matter — Parts per Million.	
		Influent.	Effluent.
163	1.82	124	46
164	1.64	113	31
165	1.20	74	21
168	0.75	58	35

Period No. 3.

Duration. — This period extended from November 11 to 22, inclusive, and included two minor rises of the river.

Character of the Plain Subsided Water. — For the most part the suspended material present in the plain subsided water was fine clay, rather difficult of coagulation. The weight of suspended matters ranged from 45 to 150 parts and averaged 78 parts, and the character of the material was typical of that which comes from rises far up the valley.

Period of Coagulation.—The nominal period of coagulation throughout this period was 7.5 hours.

Amount of Applied Chemical. — In order to reduce the suspended solids to a point where they could be readily removed by an English filter, and at the same time not have sufficient coagulated material left in the effluent to clog rapidly the filter, it was planned to use high amounts of chemical during this period. This procedure was based on the observation that while a certain amount of chemical might be sufficient to coagulate completely a water, there was after a period of subsidence as short as the one in use (7.5 hours) a considerable portion of this coagulated material left in the

water; but that if an appreciable excess of chemical over that necessary for coagulation was added, the entire coagulated masses would settle out readily.

Working along these lines, the chemical was applied to the water at the beginning of this period at the rate of 0.75 grain per gallon, and rapidly increased until on November 14, when the filter was started again after scraping, 3.00 grains per gallon were applied. This rate was gradually decreased to 1.75 grains per gallon at the close of the period, the average for the period being 1.95 grains.

Cleaning of the Basin.— Basin E was not cleaned during this period, and had not been cleaned since the baffle walls were re-arranged between September 26 and October 28. There was therefore a considerable amount of coagulated material present, which may have been more or less stirred up in starting the flow through the basin on November 11, when its use was recommenced, and on November 14 and 19, when it was started after a short interval of rest during the scraping of filter No. 16.

Character of the Effluent of the Basin. — No special examinations of the effluent from basin E were made during this period except for suspended solids. The principal noteworthy point in this connection was the amount of suspended hydrate in the effluent. As explained above, it was planned to use rather high amounts of chemical during this period in order to remove, if possible, the difficulty arising from hydrate passing on to the filter with a resultant rapid clogging of the sand layer. As the samples of the effluent were collected, they did not show any indications of the presence of chemical; but after standing in the bottles coagulation of the suspended matters became more complete and relatively large amounts of hydrate settled out. It was very evident from the results

that the chemical added had not been sufficient in any case to bring about rapid clarification in this basin, due to an excess of chemical. To a great extent this seems to have been due to the character of the suspended matter in the plain subsided water which, as noted above, was difficult to coagulate. Practically speaking, the chemical added to this water was the same as was necessary for complete clarification in half-gallon bottles in 24 hours. It was, however, considerably in excess of that which was required on the average for the complete clarification in half-gallon bottles of waters containing the same amount of suspended matter, as is shown by the following table:

Number of Lot.	Suspended Matters—Parts per Million.	Grains per Gallon of Applied Chemical.		
		Added to Influent Basin E.	Required to Clarify in Half-gallon Bottles.	
			Actual Amounts for this Water.	Estimated from Average Data.
173*	43	0.88	.....	.....
174	135	1.51	2.50	1.92
175	128	3.00	2.75	1.85
176	64	1.90	2.00	1.57
177	106	2.81	2.00	1.78
179	69	2.07	2.25	1.60
180	46	1.78	1.75	1.38
Av. excl. 173	91	2.18	2.21	1.68

*Partial lot.

The resultant action of the large amounts of chemical which passed on to the filter were very marked. On November 11 the loss of head on filter No. 16 was 1.80 feet, but by 12 P. M. on November 13 this had increased to 4.0 feet (or at the rate of 1.1 feet per day), and it was necessary to

scrape the filter. The filter was again started on November 14 at 5 P. M. with an initial loss of head of 0.4 foot, and by November 18, at 11:45 P. M., the head had increased to 4.0 feet, or at the rate of 0.9 foot per day, and it was again necessary to scrape the filter.

The average results of operation of basin E, with regard to the clarification and amounts of chemical used, during this period are given in the following table:

Summary of Average Results from the Operation of Basin E by Lots—Period No. 3.

Number of Lot.	Grains per Gallon of Applied Chemical.	Suspended Matter—Parts per Million	
		Influent.	Effluent.
173 (Partial)	0.88	43	41
174	1.51	135	98
175	3.00	128	28
176	1.90	64	25
177	2.81	106	29
179	2.07	69	28
180	1.78	46	14

Filter No. 16 was being scraped during the use of lot No. 178.

From November 22 to December 24 basin E was practically not used. On December 8 and 9 chemical was applied irregularly, but owing to continued freezing of the solution in the chemical feed-pipe no satisfactory operation of the basin could be maintained, and it was accordingly taken out of service for a time.

During the above interval the baffle walls in this basin were again remodeled, this time to practically a simple division of the tank into four compartments of equal maximum

width. The inlet and outlet pipes were also re-arranged to allow of the use of the basin for special experimental work, or in connection with filter No. 16 as desired. These modifications are described in detail in Chapter II, page 73.

Period No. 4.

Duration.—This period began on December 24, 1898, and extended to January 13, 1899. During this time the operations were confined to determining, in so far as practicable, the relative advantage of longer periods of subsidence than had been used heretofore.

Character of the Plain Subsided Water.—During this period the subsided water was fairly turbid most of the time, but it was never excessively high in suspended matter. From January 3 to 6, inclusive, river water which had not been allowed to settle for more than about three hours (incidental to the passage through the system) was handled by this system instead of subsided water. The maximum, minimum, and average amounts of suspended matter in the influent of basin E were 243, 21, and 76 parts per million, respectively.

The Period of Coagulation.—From December 24 to 28 a period of 12 hours of average displacement was employed, and from December 28 to January 3 the period was 15 hours. On January 3 the effluent was turned on to filter No. 16 after an average period of 18 hours' subsidence. Filter No. 16 was shut down to scrape on January 10, but basin E was continued in operation through January 11 with a normal period of 18 hours' subsidence.

Amount of Applied Chemical.—The amount of chemical applied to the water was adjusted, as nearly as previous experience and judgment would allow, to that necessary to reduce the suspended matter in the water to less than 40 parts per

million, and at the same time avoid the passage of coagulated material on to the filter.

Cleaning the Basin.—The basin was cleaned at the beginning, but not during the period.

Character of the Effluent of the Basin.—Practically without exception the effluent of this basin was free from suspended matters to a degree which would allow of sufficient clarification and purification of the water by filters of the English type. On the other hand, there was always present more or less aluminum hydrate which would tend to clog the filters. None of the samples showed any evidence of coagulation as they were first collected, but they all showed the presence of coagulated masses after standing for a few hours. In order to learn exactly what significance this chemical remaining in the effluent had in regard to clogging the filter, filter No. 16 was started on January 3 at a rate of 3.70 million gallons per acre per day, receiving the effluent from basin E.

In the following table are presented the leading results of operation of this basin during Period No. 4. The amount of chemical remaining in the effluent, as judged after subsidence in bottles for six hours, is recorded by letters under the amount of suspended matter: S = Slight, C = Considerable, H = Heavy. The effect of this chemical on filter No. 16 is shown by the loss of head on this filter as recorded at midnight on each day of operation. As a guide to the increased clogging effect of the amount of suspended matter passing on to the filter, the loss of head of filter No. 4 at a rate of four million gallons per acre per day for the first part of period No. 2 on this filter has been recorded. During this period the suspended matters in the water applied to filter No. 4 ranged from 9 to 80 parts per million and averaged 39 parts, which is practically double the amount that was applied to filter No. 16.

In this connection it is to be noted that the temperature of the water in the two periods compared, which averaged 35 and 56 degrees Fahrenheit on filters Nos. 16 and 4, respectively, may have accounted in a small measure for the difference in the operation of these filters due to the increased viscosity of the colder water. This is hardly probable, however, viewed from a practical standpoint.

Summary of Results of Operation of Basin E by Days—Period No. 4.

Date—1898	Average Period of Subsidence — Hours.	Average Grains of Applied Chemical.	Average Suspended Matters. Parts per Million.		Loss of Head at 12 P. M. Filter No. 16. — Feet.	Period No. 2 of Filter No. 4.	
			Influent.	Effluent.		Applied Suspended Matters. — Parts per Million	Loss of Head at 12 P. M.† — Feet.
Dec. 24..	12	2.5	110	12 S	.....	.....	.....
" 25..	12	4.0	91	18 H	.....	.....	.....
" 26..	12	3.5	90	16 C	.....	.....	.....
" 27..	15	2.5	72	16 C	.....	.....	.....
" 28..	15	2.25	81	18 C	.....	.....	.....
" 29..	15	1.75	80	20 C	.....	.....	.....
" 30..	15	2.00	78	22 C	.....	.....	.....
" 31..	15	1.50	59	19 S	.....	.....	.....
1899. Jan'y 1..	15	1.50	49	17 C	.....	.....	.....
" 2..	15	1.50	49	21 S	.....	.....	.....
" 3..	18	1.00	75*	12 C	0.7	26	0.5
" 4..	18	2.20	56*	16 S	1.2	35	0.5
" 5..	18	2.50	151*	14 S	1.5	19	0.5
" 6..	18	2.70	116*	20 C	2.0	28	0.5
" 7..	18	2.50	130	17 S	2.4	9	0.6
" 8..	18	2.40	117	19 S	3.1	37	0.7
" 9..	18	1.75	54	10 S	3.3	37	1.0
" 10..	18	1.80	106	22 S	Scraped.	80	1.1
" 11..	18	.....	.....	98	.....	38	1.2

* River water. † On corresponding days after scraping.

THE FILTERS OF THE MODIFIED ENGLISH SYSTEM.

The two filters operated in connection with the modified English system were numbered 16 and 17 respectively. Except in the manner of operation in regard to rate of filtration, these filters were duplicates, and the detailed descriptions of their construction have been presented in Chapter II, page 76. As a matter of convenience the leading features of construction will be briefly summarized here.

Construction of Filters Nos. 16 and 17.

These filters were constructed in the tanks originally used for filters Nos. 6 and 12. The coarse sand of the original filters was removed to the mortar sand which formed the upper layer of the underdrains. There was then placed in each filter thirty inches of fine sand which had been thoroughly washed, a portion of it having been removed in a clogged condition from the fine sand filters. There were no other modifications in these filters except that a new inlet pipe was constructed to convey the effluent from basin E to the open compartment above the sand in these two filters.

DESCRIPTION OF THE NORMAL OPERATION OF FILTERS NOS. 16 AND 17.

These filters were operated in the same general manner as the original filters of the English type (see pages 130 to 135). As a matter of record and convenience the leading points are reviewed briefly in regard to these filters.

Continuous Plan—These filters were operated on the continuous plan, filtration being continued at the same rate from one scraping to the next. The applied water was admitted freely from the regulating tank through basin E, and normally

stood from 3.5 to 4.0 feet deep above the sand layer. During filtration the outlet pipe was left wide open as far as the valve at the end of the pipe near the meter.

Regulation of Rate.—The rate of filtration was regulated by adjusting a valve on the end of the outlet pipe in the meter-room below the platform. Observations were made of the rate three times each day, and adjustments were made when the rate differed from the normal by more than 5 per cent.

Loss of Head—The loss of head observations were made three times daily, about fifteen minutes after adjusting the rate of filtration.

Collection of Samples.—Samples of the effluent of each filter and of the subsided water as it was delivered to the system were collected three times daily for bacterial analysis, and once daily for chemical analysis and for inspection of the clearness of the effluent. Complete chemical analyses, however, were made on mixed samples representing three or four days. Samples of the effluent from basin E (the water applied to the filters) were also collected three times daily for chemical analysis during the periods when chemical was being applied to the water in connection with this system.

Rate of Filtration.—Filter No. 17 was operated at a rate of 2.60 million gallons per acre daily. The rate of filtration of filter No. 16 was 4.00 million gallons per acre daily up to September 27, when the rate was increased at the beginning of period No. 4 of this filter to 5.00 million gallons per acre daily. This rate was maintained up to December 10, when this filter was taken out of regular service. It was started again after scraping at 3.70 million gallons per acre daily for one period in order to determine the effect of 18 hours' subsidence in the removal of coagulated material. This lower rate was necessitated by the capacity of basin E, which would only

provide an average period of coagulation and subsidence of 18 hours at this rate.

Head Utilized.—On the first period for these filters the loss of head was carried to 4.00 feet. This gave about 0.5 foot negative head, owing to the level of the water in these filters being somewhat lower (on account of friction in the extra piping) than the level in the other filters. When first scraped it was found that this negative head had caused a release of air from the water, and that the air upon breaking through had very badly disturbed the clogged surface layer of sand. After this the filters were regularly scraped at the full positive head of 3.5 feet until No. 17 was shut down. With only No. 16 in service the water was carried higher in the filter and 4.0 feet were utilized.

Scraping.—In all cases the surface of the sand layer of filters Nos. 16 and 17 were scraped so as to remove practically all of the clogged material. There was at all times a distinct plane of demarcation between the dirty and clean sand, and this made the depth of scraping readily determinable. The deep penetration of fine clay particles, such as occurred with the English filters receiving plain subsided water during freshets, did not occur on these filters.

Depth of Scraping.—The normal thickness of clogged sand layer was from 0.75 to 1.00 inch, and this layer was entirely removed in scraping.

Filling from Below.—After completion of scraping, these filters were filled from below with filtered water at the same rate as it passed down through the sand during filtration. Filtered water was allowed to fill the entire sand layer and the space above the sand to the inlet opening. The supply of filtered water was then shut off and the inlet opened slowly. Water to be filtered was admitted slowly at first to avoid dis-

turbance of the sand layer, and then more rapidly until the space above the sand layer was entirely filled.

Resumption of Filtration.—As soon as the space in the filters above the sand layer was entirely filled, the outlet was opened and filtration was begun at the normal rate with no wastage.

Discontinuance of Filters.—Filter No. 17 was operated from August 8 to September 25, when it was shut down in order to provide more water for filter No. 16, which it was desired to operate at a higher rate. On December 10 trouble was experienced in operating this system, owing to freezing in various pipes, notably the chemical supply pipe. Filter No. 16 was scraped on December 13, and several attempts were made to start it in regular service again, but the continued cold weather prevented this being accomplished in a satisfactory manner, and the filter was considered out of regular service after December 13, 1898. From January 3 to 10, 1899, this filter was operated at a rate of 3.70 million gallons per acre for special experiments on clogging, as already stated. It was not started again after this latter date.

CHARACTERISTIC FEATURES OF OPERATION OF FILTERS NOS. 16 AND 17.

In the tables at the close of this chapter are presented the leading average results of operation of filters Nos. 16 and 17, and the individual results are given in Appendix II. The leading features of the results of operation will be presented briefly here, and will be discussed in Chapter VII.

Character of the Applied Water.—It was originally intended to treat the water before passing it on to these filters so as to remove from it all suspended matters in excess of 50 parts per million. Later this limit was reduced to about 40 parts as a result of wider experience in the operation of these filters at

increased rates of filtration. Furthermore, it was believed to be essential to allow sufficient subsidence to take place, so that but little if any of the coagulated material should pass on to the surface of the filters.

These filters were started in operation on August 8, and from that date to September 1 chemical was regularly applied to the subsided water before it entered basin E. During this period the maximum, minimum, and average daily amounts of suspended matters in the effluent of tank E which was applied to the filters were 76, 24, and 49 parts per million, respectively.

From September 1 to October 28 the amount of suspended matters was below the limit set for the operation of this system, and no chemical was used. During this period the maximum, minimum, and average daily amounts of suspended matters applied to these filters were 75, 24, and 51 parts per million, respectively. Filter No. 17 was permanently stopped on September 25.

Application of chemical was resumed on October 28 and continued until November 1. Chemical was applied on November 5, and again from November 11 to 22. During this period the suspended matters passing on to filter No. 16 ranged from 24 to 75 and averaged 45 parts per million.

From November 22 to December 8 no chemical was used in connection with this system. On December 8, 9, and 10 chemical was applied at the inlet to basin E. The suspended matters in the applied water during this period ranged from 20 to 110 and averaged 36 parts per million.

In regard to the presence of coagulated masses in the water applied to the filters, the evidence has already been presented in connection with the operation of basin E, and it need only be stated here that there was at all times during the applica-

tion of chemical to the subsided water some hydrate left in the water as it passed on to the filters. The amount present during August was not great, as judged from the clogging of the filters. During the fall and winter rises, however, there was at all times a considerable amount of the effluent from basin E when chemical was applied to the influent to this basin. While the coagulated masses remaining in the effluent of basin E were very small, as judged by inspection, yet the evidence is clear that they were retained at and very near the surface of the sand layer.

Period before the Character of Effluent became Normal.—The length of time which elapsed between first starting these filters and when the character of the effluent reached the normal was much shorter than in the case of the other English filters. This was due apparently to two reasons. First, the amount of suspended matters in the applied water was under 50 parts per million on an average from the start; and, second, the sand used in the construction of these filters was for the most part washed sand which had been removed from other filters in a clogged condition. It seems probable that the sand was initially more efficient both on account of its relative freedom from bacteria and other matters which would be readily washed out during filtration, and also on account of the sand having more or less gelatinous organic matter attached to its surface. Under these conditions these filters apparently reached normal operation in less than ten days, as compared with nearly three weeks for the original English filters.

Disturbances of the Surface of the Sand Layer.—These filters were not operated during the period favorable for rapid fish development, and no trouble was experienced from this form of life. During September earthworms caused serious disturbances, however, in both of the filters.

SUMMARIES OF THE PRINCIPAL RESULTS OBTAINED FROM THE OPERATION OF FILTERS NOS. 16 AND 17.

In the three following tables are presented averages of all of the leading results of operation. These tables are made up in the same manner as those in Chapter IV, and reference is made to detailed descriptions of the former tables just preceding their presentation, pages 154 to 159.

Table No. 1.—In this table are presented all of the leading quantitative results of operation of filters Nos. 16 and 17, arranged and averaged by periods. The only changes from the form described and presented in Chapter IV are that no reference is made to reductions in rate of filtration or to subsidence of the water above the sand layer, those procedures not having been used with these filters.

Table No. 2.—All of the results of special bacterial analyses at times of scraping and the leading averages of regular samples at these times are presented in this table.

Table No. 3.—The leading qualitative results of operation averaged by months are given in this table, with percentages of removal.

Table No. 4.—The last table contains the average results by months of chemical and bacterial analyses of both effluents, including and supplementing the data of Table No. 3.

TABLE No. 1—*Summary of Quantitative Results of Operation of the Filters of the Modified English System, arranged by Periods.*

Filter No. 16.

Number.	Period. Began. 1898	Length. Days.	Average Parts per Million of Applied Suspended Matter.	Loss of Head. Feet. Initial.	Final.	Condition of Sand Surface before Scraping.	Average Rate of Filtration in Million Gallons per Acre Daily. Actual.	Net.	Quantity of Effluent in Million Gallons per Acre.	Sand Removed. Thickness of Layer in Inches.	Volume in Cubic Yards. Per Acre of Surface.	Per Million Gallons of Effluent.	Per Ton of Applied Suspended Matter.
1	Aug. 8, 3.30 PM	18.90	51	0.3	4.2	Badly pitted with airholes.	4.00	3 85	72.77	0.90	121	1.66	7.8
2	Aug. 28, 1.05 AM	12.85	30	0.2	0.6*	Badly disturbed by worms.	3.98	3.73	47.90	0.79	106	2.21	17.7
3	Sept. 9, 9.20 PM	17.93	15	0.2	3.6	Normal	4.02	3.77	67.58	0.57	77	1.13	18.3
4	Sept. 27, 7 45 PM	23.84	23	0 5	3.5	Normal	4.98	4.86	116.11	0.86	115	0.99	10.33
5	Oct. 21, 4.00 PM	12.99	28	0.6	4.0	Gelatinous	4.91	4.68	61.03	1.03	139	2.27	19.5
6	Nov. 3, 3.50 PM	11.05	54	0.4	4.0	Gelatinous.	4.77	4.38	48.36	0.90	121	2.52	11 1
7	Nov. 14, 5.00 PM	5.04	27	0.5	4.1	Gelatinous	4 90	4.15	22.46	0.98	132	5.88	52.2
8	Nov. 18, 6.00 PM	5.30	34	0 5	2.1†	Frozen	4.72	3.80	20.11	0.66	89	4.41	31.2
9	Nov. 25, 1 15 AM	15.22	35	0.5	2.6	Gelatinous	4.95	4.03	75.10	0.83	112	1.48	10.2

Filter No. 17.

1	Aug. 8, 5.30 PM	22.56	50	0.2	3.5	Normal	2.54	2.45	55.05	0.76	102	1.85	8.9
2	Aug. 31, 6.20 PM	21 75	19	0.2	1.1‡	Badly disturbed by worms.	2.62	2.39	51.83	0.51	69	1 32	16.8

* Maximum loss of head 1.3 feet. † Filter accidentally allowed to drain out. ‡ Maximum loss of head 1.4 feet.

TABLE No. 2—*Results of Bacterial Examinations of Effluent to show the Effect of Scraping.*

Bacteria per Cubic Centimeter.

Filter No. 16.

Date of Scraping—1898.	Average Results of Regular Samples on Days preceding Scraping		Special Results after Passage of Stated Quantities of Effluent in Million Gallons per Acre after Scraping.								Average Results of Regular Samples.		
											Day of Scraping.	Days after Scraping.	
	Second.	First.	0.15	0.27	0.39	0.51	0.63	0.87	1.20	Ave.		First.	Second.
August 28	31	32	44	27	29	24	45	29	32	33	33	25	36
September 9	29	26	140	50	60	50	60	21	55	60	55	160	110
September 27	9	13	28	18	39	49	39	42	44	37	44	24	22
October 21	17	46	12	22	40	50	50	75	75	46	85	39	20
November 3	8	14	17	36	100	130	130	110	150	95	150	150	110
November 14	65	38	90	110	230	275	160	325	180	200	130	50	30
November 19	31	17	49	47	80	25	75	65	25	55	24	48	20
November 25	40	140	50	170	170	220	210	220	120	160	190	200	180
Average	29	37	55	60	95	100	95	110	85	85	90	85	85

Filter No. 17.

August 31	25	26	65	33	24	32	38	46	35	39	49	24	28
September 21	20	25	48	120	130	90	38	14	23	65	80	20	19
Average	22	25	55	75	75	60	38	30	29	50	65	22	24

TABLE No. 3.

Summary of the Leading Qualitative Results of Operation of the Filters of the Modified English System, arranged by Months.

Filter No. 16.

Month. 1898.	Temperature of Effluent. Deg. C.	Rate of Filtration. Million Gallons per Acre Daily.	Suspended Matter. Parts per Million.		Total Organic Matter.* Parts per Million.		Percent. Removal.	Bacteria per Cubic Centimeter.		Bacterial Efficiency.
			Subsided Water.	Effluent	Subsided Water.	Effluent.		Subsided Water.	Effluent.	
August.....	25.0	3.70	51	3	{ .185 { 4.0	.074 1.4	60.0 65.0	3,100	110	96.5
September ..	23.0	3.92	18	2	{ .130 { 2.6	.079 1.8	39.2 30.8	2,200	36	98.4
October	16.0	4.90	16	1	{ .114 { 2.0	.066 1.2	42.0 40.0	3,200	21	99.3
November ..	7.0	4.32	41	4	{ .179 { 4.3	.082 2.0	54.2 53.5	10,400	80	99.2
December ...	2.6	4.79	38	7	{ .141 { 3.1	.079 1.9	44.0 38.7	17,000	900	94.7

Filter No. 17.

August.....	25.0	2.37	51	2	{ .185 { 4.0	.074 1.4	60.0 65.0	3,100	120	96.1
September ..	23.0	2.55	18	2	{ .131 { 2.7	.076 1.6	42.0 40.7	1,800	25	98.6

* The first (upper) figures in each bracket represent the nitrogenous matter (nitrogen as albuminoid ammonia) and the second (lower) the carbonaceous matter (oxygen consumed).

TABLE No. 4.

Average Results of Chemical and Bacterial Analyses of the Effluent of Filters Nos. 16 and 17, arranged by Months.

[Chemical Results expressed in Parts per Million.]

Months—1898.	Filter No. 16.					Filter No 17.	
	Aug.	Sept.	Oct.	Nov.	Dec.	Aug.	Sept.
Oxygen consumed	1.4	1.8	1.2	2.0	1.9	1.4	1.6
Nitrogen as albuminoid ammonia	.074	.079	.066	.082	.079	.074	.076
Nitrogen as free ammonia	.024	.021	.019	.018	.018	.025	.022
Nitrogen as nitrites	.000	.000	.000	.000	.000	.000	.000
Nitrogen as nitrates	0.54	0.49	0.48	0.80	0 82	0.55	0.49
Total residue on evaporation	122	146	160	130	126	123	138
Alkalinity*	32	42	50	36	49	32	41
Sulphuric acid	34	24	23	29	26	31	22
Dissolved oxygen	3.8	5.5	5.3	7.1	10.7	3.1	4.9
Bacteria per cubic centimeter	110	36	21	80	900	120	25

*In no case were the effluents acid due to undecomposed sulphate of alumina, or was the amount of alkalinity less than would have sufficed to have decomposed two additional grains of chemical per gallon.

CHAPTER VII.

Discussion of the Leading Factors associated with the Efficiency and Cost of Operation of the Modified English System of Purification, based on the Results of these Experiments.

In this chapter there is discussed the evidence presented in Chapter VI with reference to the use of a coagulating chemical (sulphate of alumina) in conjunction with subsidence, to prepare adequately the Ohio River water at Cincinnati during floods for successful filtration with filters of the English type. The premises upon which this portion of the investigations is based were stated at the beginning of Chapter VI, page 242.

Portion of the year 1898 when supplementary treatment would have been required after plain subsidence for three days in the clarification and purification of the local water for English filtration.

As shown in Chapter V, page 180, it was learned conclusively that there is a certain limit in the amount of suspended clay in the subsided water, above which English filters do not regulary give satisfactory results. This limit when expressed by weight of clay varies somewhat, due to differences in the character of the clay particles and to the retentive capacity of the sand layer of the filter. Ordinarily this maximum limit ranged from 30 to 70 parts, and averaged about 50 parts per million, or a little less, for amounts of clay which English

filters constructed and operated as in the case of filter No. 16 can handle regularly. But for two or three days or more at the beginning of a rise the retentive capacity of the sand layers allows the suspended clay to exceed materially 70 parts and still give satisfactory results; although, at the end of rises, an overtaxing of the retentive capacity would cause a washing out of the stored clay to a degree which would offset in a measure the advantage gained at the beginning of a rise. For very thick sand layers and very low rates of filtration, which were discussed in Chapter V, page 240, and dismissed as inadmissibly expensive, this limit in applied clay is of course too low.

On an average plain subsidence for three days effects a removal of substantially 75 per cent of the suspended matters in the Ohio River water at Cincinnati, as was shown in Chapter III, page 124.

On the above basis, that the amounts of applied clay in excess of 50 parts per million determines those days on which for practicable conditions of filtrations supplementary preliminary treatment would be needed in addition to plain subsidence for three days, it is found that, during the fairly normal year 1898, they aggregated 168 days, or about 5.5 months. But the storage capacity for clay particles during short rises of filters, constructed and operated within conventional limits as to thickness of sand layer and rate of filtration, would have caused the extra treatment to be unnecessary for the full number of days noted above. In fact, the actual data indicate that supplementary preliminary treatment under the conditions stated would have been needed on only about 134 days in 1898, or about 4.5 months.

The distinctive feature of the modified English system, therefore, is to find the most practicable means of the further

removal of clay from the plain subsided water for about 4.5 months in the year. And it is instructive to note that this period of required supplementary treatment in 1898 was made up of about eight shorter periods of varying length and of irregular occurrence which could not be foretold. This is shown more clearly by the following table, in which are recorded those days in 1898 when English filters would have treated the plain subsided water successfully (marked S) without additional preparation, and those days (aggregating 134) when the filters would have failed (marked F), and supplementary treatment would have been required, based on the results of these tests.

Table showing those Days in 1898 when English Filters would be Successful (S) and when they would Fail (F) in the Clarification and Purification of the Ohio River water at Cincinnati after Plain Subsidence for three Days.

Day.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	S	F	S	S	S	S	S	F	S	S	F	S
2	S	F	S	S	S	S	S	F	S	S	F	S
3	S	F	S	S	S	S	S	F	S	S	F	S
4	F	S	S	S	S	S	S	F	S	S	S	S
5	F	S	S	S	S	S	S	F	S	S	S	S
6	F	S	S	S	S	S	S	F	S	S	S	F
7	F	S	S	S	S	S	S	F	S	S	S	F
8	F	S	S	S	S	S	S	F	S	S	S	F
9	F	S	S	S	S	S	S	F	S	S	S	F
10	F	S	S	S	S	S	S	F	S	S	F	F
11	F	S	S	S	S	S	S	F	S	S	F	F
12	F	S	S	S	S	S	S	F	S	S	F	F
13	F	S	S	S	S	S	S	F	S	S	F	S
14	F	S	S	S	S	S	S	F	S	S	F	S
15	F	S	S	S	S	S	S	F	S	S	F	S
16	F	F	S	S	S	S	S	F	S	S	F	S
17	F	F	S	S	S	S	S	F	S	S	F	S
18	F	F	F	S	S	S	S	F	S	S	F	S
19	F	F	F	S	S	S	S	F	S	S	F	S
20	F	F	F	S	S	S	S	F	S	S	F	S
21	F	F	F	S	S	S	S	F	S	S	F	F
22	F	F	F	S	S	S	S	F	S	S	F	F
23	F	F	F	S	S	S	S	F	S	S	F	F
24	F	F	F	S	S	S	S	F	S	S	F	F
25	F	F	F	S	S	S	S	F	S	S	F	F
26	F	F	F	S	S	S	S	F	S	F	S	F
27	F	S	F	S	S	S	S	F	S	F	S	F
28	F	S	F	S	S	S	F	F	S	F	S	F
29	F	.....	F	S	S	S	F	F	S	F	S	F
30	F	.....	F	S	S	S	F	F	S	F	S	F
31	F	.....	S	.....	S	.....	F	F	.....	F	.....	F

RANGE AND AVERAGE AMOUNT OF REQUIRED CHEMICAL FOR SUPPLEMENTARY CLARIFICATION OF PLAIN SUBSIDED WATER.

Experience shows that it is a difficult matter to estimate accurately the amount of chemical required to reduce, with the aid of subsidence, any given weight of suspended matter to within the limit of 50 parts. This is due largely to the variations in the size and character of the suspended clay particles. Thus it was learned clearly that less chemical is required at the beginning than at the end of a long freshet to coagulate equal weights of suspended matter so that they may be removed by subsidence.

A careful study has been made of the available data, which, for convenience and explicitness, are arranged in several groups or grades of subsided water with reference to the weight of the suspended clay. On an average it is believed that the data are perfectly trustworthy, practically speaking. But, for the maximum and minimum amounts indicating the range for each grade, the data are too few to warrant definiteness being given to these figures.

In general terms, however, the following table illustrates reasonably well the ranges in each grade which might be expected in practice, the lower quantities corresponding to the early part of freshets and the higher ones to the latter portions of rises coming from the upper part of the valley, with opportunities for the deposition of the coarser particles in the stream. The table is presented without further comments beyond the fact that in practice there are many associated points to serve as a guide to the one in question.

Table showing the Range and the Normal Amount of Chemical required for the Necessary Clarification of Different Grades of Turbid Subsided Water.

Grade of Subsided Water. Suspended Clay in Parts per Million.		Amounts of Sulphate of Alumina. Grains per Gallon required for the average amount of Suspended Clay.		
Range.	Average.	Maximum.	Minimum.	Normal.
51–100	75	1.50	1.00	1.30
101–200	150	2.25	1.75	2.00
201–300	250	2.55	2.05	2.30
301–400	350	2.85	2.35	2.60

Relative to the average amount of required chemical, based on experience in the operation of basin E, it is estimated that there would have been needed 1.50 grains per gallon for the 134 days in the year when it would have been actually applied in 1898. This is equivalent to an annual average of 0.55 grain per gallon.

DISPOSITION OF APPLIED CHEMICAL.

From present evidence there is no reason to believe that with proper attention there would be any likelihood of the amount of applied chemical being sufficiently great to exceed that which could be decomposed by the alkaline compounds of the river water. That is to say, there is no probability that undecomposed chemical would reach the filtered water. This is on the basis that the subsided water would never contain over 400 parts of suspended matter, an assumption which seems perfectly safe, especially as it would be practicable to stop the river water pump occasionally, if need be, at times of maximum suspended matter in the river water.

At times of heavy freshets the margin of alkalinity would not be great, owing to the dilution of the alkaline compounds of the river water. But there seems to be no reason to believe that the alkalinity would be insufficient during any ordinary conditions of the river. If future experience should show that during more extreme and long-continued freshets than have yet been studied, and such as occur, if at all, only a very few times in the course of a century, the relative margin of alkalinity is smaller than the present records indicate, then it would not be a difficult or expensive matter to arrange for an application of a small amount of soda or other alkali to the river water at the pumping station. In other words, this phase of the process is capable of successful management.

Accordingly, the disposition of the applied chemical practically refers to two lines, as follows:

1. The dissolved carbonates of lime and magnesia which are converted in equivalent amounts into dissolved sulphates of those bases; and to the equivalent quantity of carbonic acid set free and dissolved in the water. One grain per gallon of sulphate of alumina requires for its decomposition from 6 to 8 parts of alkalinity, depending upon the amount of chemical absorbed by the suspended matter of the subsided water (see page 287). The increase in calcium sulphate (incrusting constituents) is proportional to the decrease in alkalinity, while the increase in carbonic acid gas is 44 per cent of the decrease in alkalinity.

2. The gelatinous and insoluble aluminum hydrate which coagulates the clay by causing aggregations into masses much larger than the original clay particles.

With regard to the first line, the chemical would be applied only at such times that the passage of sulphates of lime and magnesia and of carbonic acid into the filtered water, and the

reduction in the carbonates of those bases, would not ordinarily make the total quantities of the former constituents materially in excess of those naturally present in the river water during the low stages of water. So far as can be learned, the effect upon the human system of converting the carbonates of lime and magnesia into sulphates would be practically *nil*. Practically speaking, it is doubtful whether these added constituents would ever be detected by steam-raisers except by analysis. It follows from the statements above that the sum of the alkalinity and incrusting constituents, representing the soap-consuming power of the water, is unaffected by the application of this chemical.

Concerning the suspended aluminum hydrate, and the masses of clay more or less coagulated and aggregated thereby, the situation is different. In order that English filters may not be clogged too rapidly, making the surface scrapings come too often to be practicable, it is necessary that these aggregated masses of coagulated clay particles be removed completely, or nearly so, before the water reaches the filters.

The disposition of the coagulated clay before the water reaches the filters is an imperative step in this system. It is accomplished by subsidence (basin E in the experimental plant), and this portion of the system is next considered.

THE PERIOD OF SUPPLEMENTARY SUBSIDENCE NECESSARY FOR THE ADEQUATE REMOVAL OF COAGULATED MASSES OF ALUMINUM HYDRATE AND CLAY.

A practically complete removal of the coagulated masses of aluminum hydrate and clay is an absolute necessity in this process, as was stated in the last section. To effect this was found to be a more difficult matter than the early evidence indicated to be the case.

Basin E was operated on the continuous displacement plan, so that at different times the average periods of subsidence were practically 5, 8, 12, 15, and 18 hours. During August (period No. 1, as described in Chapter VI, page 249) the evidence indicated that the coagulated material could be sufficiently removed, with an average period of 8 hours for supplementary subsidence. But later the experience with this period of subsidence showed repeated failures to accomplish the desired end. In fact the data show that with 18 hours as the period of average subsidence, the amount of coagulated material going on to the filter was clearly too high.

These apparently inconsistent results are explained, so far as our knowledge goes, in part by difference in character of the suspended clay, but chiefly by the influence exerted by the amount of applied chemical. This point is taken up in the next section.

Taking every thing into consideration, the present evidence indicates that on a practicable basis an average period of less than about 24 hours could not uniformly be depended upon to accomplish the required purpose.

ON THE INFLUENCE EXERTED BY THE AMOUNT OF APPLIED CHEMICAL UPON THE REQUIRED PERIOD OF SUPPLEMENTARY SUBSIDENCE.

Towards the close of the work it was found that the amount of applied chemical was a factor of far more significance, with reference to the required period of subsidence for the removal of the coagulated clay, than was apparent at the outset. In the light of the full available evidence, it appears that adequate clarification for this system is effected most quickly by the application of a certain amount of chemical appreciably less than suffices for complete coagulation, or by a comparatively

large quantity distinctly in excess of that required for complete coagulation. With amounts of chemical intermediate between these extremes, the period of supplementary subsidence apparently must be materially extended.

The minimum amount of chemical may be defined as that which satisfies the "absorptive action" of the clay, and just begins to make more complete the coagulation for each small fraction of chemical added. By the absorptive action is meant that power which the clay in subsided water possesses of receiving an application of chemical up to a certain point without any resultant clarification after subsidence, beyond that which would occur if no chemical had been added. In many instances this is quite marked, as is illustrated by the results of an actual typical experiment, as follows:

Applied Sulphate of Alumina in Grains per Gallon.	Parts per Million of Clay in the Water after 24 Hours' Subsidence. *	Parts of Clay removed per Successive 0.25 Grain of Chemical.
0.0	76	..
1.50	75	0
1.75	63	12
2.00	20	43
2.25	3	17

*Original amount of suspended matters, 455 parts per million.

In practice it may be stated that it would be almost impossible for one uniformly to apply this chemical in such quantities as would accomplish the clarification, and at the same time keep the amount of chemical so small that practically none would remain in the water after subsidence for about eight hours. This could doubtless be managed reasonably well during long rises, when the subsided water was approximately uniform day after day, as was the case during the latter part of August.

But to do it at all times is impossible in the light of our present knowledge.

When the chemical is applied in quantities materially in excess of that required for complete coagulation, there is a marked tendency for the coagulated materials to subside somewhat more quickly. To avail of this on a large scale is not practicable on the ground of cost alone.

From this it is concluded that while it is theoretically possible to apply a chemical in such amounts as to clarify the water sufficiently in much less than 24 hours, yet on a large scale with sulphate of alumina such a procedure is impracticable, and this full period of subsidence would be required.

ON THE INFLUENCE EXERTED BY THE METHOD OF OPERATING THE SUPPLEMENTARY SUBSIDING BASIN UPON THE REQUIRED PERIOD OF SUBSIDENCE.

Basin E was operated on the continuous displacement plan. The evidence indicated that a part of the water passed through the basin in about 50 per cent of the average time computed from the displacement of the water, while some of it lagged behind and took 150 per cent of the average period for its passage through the basin. At times the efficiency of the basin may have been greater, but it is doubted whether in practice a basin could be uniformly operated on this plan and prevent the passage of some of the water at the outlet in a comparatively small percentage of the average time.

By operating a basin on the "fill, quiescent subsidence, and draw-from-the-top" plan, it is probable that better results would be obtained. But experience showed that, with reasonably large application of this chemical, masses of coagulated clay were found in the water after subsidence for 24 hours.

This makes it very questionable whether the advantage of this method of operation would compensate for the extra cost.

ON THE RELATIVE PRACTICABILITY OF APPLYING CHEMICALS TO MUDDY RIVER WATER BEFORE AND AFTER PLAIN SUBSIDENCE.

Each of these procedures has its advantages and disadvantages which are outlined here, on the basis that it is necessary to provide about 24 hours of subsidence to the water after the application of chemical, in order to guard against a rapid clogging of English filters.

Provisions for Plain Subsidence. — While 24 hours of plain subsidence under the conditions met in these tests theoretically represents, on an average, the economical limit of preliminary treatment of this kind, due to the fact that it is cheaper to remove the remaining suspended matter in a water subsided for 24 hours by the use of chemical than by further subsidence; yet, when the question of the very turbid waters of long freshets is practically considered, with the necessity of having the basins serve for storage purposes and the relatively cheaper cost of construction of large basins than of small basins at California, it seems wisest to provide an average of about 48 hours of plain subsidence.

Provisions for Coagulation and Subsidence. — In the event that the chemical would be applied after plain subsidence at times of muddy water, it would be necessary to provide a supplementary basin having a capacity of about 24 hours' supply, and operated on the continuous plan. This would be expensive to construct at California, and the fixed charge for its construction would be constant, whereas it would be needed for only about one third of the time.

If the chemical were applied in a satisfactory manner to the muddy river water as it entered the plain subsiding reservoirs, the cost of the supplementary basin would be eliminated. At first sight it would seem that it would be also possible to make a large saving in the size and cost of the plain subsiding reservoirs by this procedure. This would hardly be true, however, under the local conditions, where the subsiding reservoirs must act in part as storage basins; and especially as it would be theoretically economical to use only 24 hours for plain subsidence preceding the use when needed of a supplementary basin, as well as to use 24 hours for both coagulation and subsidence in the same reservoirs. That is to say, the size of the plain subsiding (primary) reservoir would not be affected by the method of applying this chemical when viewed from a practical standpoint.

Should the plain subsiding reservoirs (operated on the fill-and-draw plan, and used at times for coagulating reservoirs) be only two in number, it would of course mean that, if the rate of pumping equaled the rate of consumption, then one reservoir would be filled just as it would be necessary to begin drawing from it. This would hardly be practicable, as it would probably carry too much coagulated material on to the filters in the first water drawn. It could be obviated under the local conditions, however, with basins for an average period of 48 hours' subsidence, by operating the pumps, when chemical would be needed, so as to afford a few hours' subsidence for all the water in a reservoir just before drawing.

Summing up the situation, it may be stated that the application of chemical when needed to the river water before plain subsidence would save the cost of the supplementary basin, and that the same size and construction of reservoirs would serve

in the procedure for plain subsidence without chemical, and for coagulating and subsiding reservoirs with chemical (when needed). The operation would be somewhat different, but with practically no difference in cost.

Disadvantages Weighing against the Saving of the Cost of the Supplementary Basin.

Weighing against the saving of the constant fixed charges for the extra basin would be two factors of importance, as follows:

1. Somewhat larger amounts of chemical would be required when applied directly to the river water, due principally to wastage caused by the silt and coarse suspended matters.

2. This procedure would be more difficult to operate, although not necessarily more expensive, as competent men could manage a plant by either method.

The somewhat larger amounts of applied chemical at times would reduce almost completely the margin of alkalinity in the water; and it is quite likely that occasionally it would not be wise to add as much chemical as would be the case in the absence of this factor. However, this condition of affairs is not considered to be very serious under good management, because the retentive capacity of English filters would allow for such very short periods the application of abnormally high amounts of clay. As previously stated, assistance at such times could also be obtained by stopping the river water pumps for short periods.

The question of the application of chemical, both as to general procedures and quantities, is taken up at some length, as follows:

Decision as to when to apply Chemical.—The times of re-

quired application of chemical to plain subsided water would be quite readily determined from the weight of the suspended clay in the subsided water passing directly upon the filters. The decision to treat river water would, however, involve an estimate of the condition of the water after subsidence without treatment, and this would at times be a somewhat difficult proposition owing to variations in the effectiveness of subsidence with different types of water.

Decision as to the Amount of Chemical.—By reason of the removal of a large per cent of the suspended matters from the river water, the plain subsided water does not vary in average character by nearly as wide amounts as does the river water. This would render the decision as to the amount of chemical to apply much simpler with plain subsided water than river water. Expressed in amount of chemical, it is probable that the optimum treatment of plain subsided water at any time would not range more than about 0.25 grain per gallon above or below the average quantity for the amount of the suspended matters which the water contained; but in the case of river water this range would frequently be more than 0.50 grain, and might be nearly a grain per gallon at times. Already there have been presented the average amounts of chemical estimated to be required for various amounts of suspended matter in subsided water, and also the maximum and minimum amounts which would apparently be required at the beginning and end of rises in the river, respectively. Between these limits the actual amount to apply would be largely a matter of judgment based on general information, a much more difficult matter with river water than with subsided water, because of the wider range in required chemical per given weight of suspended matter, as explained above.

Rapid Methods of estimating the Amount of Suspended Matter.—It is obvious that in the operation at this place of a large purification plant of the modified system, it would be very desirable, if not necessary, to ascertain from time to time as promptly as possible the amount of suspended matter in the water to be treated. This can, of course, be done by weighing the residue on evaporation, a procedure requiring several hours at best.

During these experimental investigations much assistance was derived from optical means of estimating these suspended matters, especially by the diaphanometer, as described briefly on page 99. It was found that the estimates made on subsided water were very satisfactory, and could be obtained in a few minutes after collecting the samples. With river water the data by this method were less valuable, being liable at times of freshets to a plus or minus error of from 20 to 35 per cent in the present state of development of these methods.

There is no room to doubt but that in connection with a large plant this general method of estimating suspended matter should be further developed. For a consideration of the present status of its development, reference is made to the special paper mentioned on page 25.

Relative Amounts of Chemical required.—Upon the addition of a chemical such as sulphate of alumina to a water containing salts by which the chemical is decomposed, the reaction between these salts and the applied chemical takes place very rapidly. At the same time, however, there is an action between the applied chemical and the suspended matters present in the water, by which some of the chemical is absorbed before it is decomposed. Chemical so absorbed is wasted so far as its availability for coagulation is concerned. The amount of absorption before decomposition varies with the character of the

material, and during these experiments it ranged from 0 to 1.12 grains per gallon in the case of river water, and from 0 to 0.94 grain in the case of subsided water. The average amounts were 0.50 and 0.30 grain per gallon for river water and subsided water, respectively.

After the reaction is complete the gelatinous aluminum hydrate, which is one of the resultant products of the reaction, gradually aggregates, forming relatively large particles from numerous infinitely small centers. In this process the matters originally suspended in the water are entangled or coagulated. In order to coagulate and aggregate the fine matters to a sufficient degree, so that they will settle out readily, a certain amount of chemical (sulphate of alumina) must be applied. Below this amount the coagulation is more or less incomplete down to a point which averages from about 60 to 75 per cent of the total chemical required in the case of ordinary river water during rises. Amounts less than this approximate percentage of the optimum do not produce any noticeable effect on the suspended matters. Part of this inactive or wasted amount is accounted for by absorption before decomposition of the applied chemical. The balance seems to be used up in satisfying a certain ill-defined absorption tendency of the suspended particles for aluminum hydrate. In actual amounts in grains per gallon the total inactive chemical, as viewed from its coagulating action, is approximately as follows for river water which would require treatment with this system.

	Ohio River Water.	Plain Subsided Water (Three Days).
Maximum	2.00	1.75
Minimum	1.00	0.50
Average	1.50	1.25

Finally, in the case of river water, some of the particles of aluminum hydrate are entangled with the coarse particles of silt and clay, and are carried to the bottom before they have a chance to coagulate the finer matters. The subsidence of these coarse particles, on the other hand, seems to set up small eddies and currents, by which the coagulant is apparently brought more intimately in contact with the suspended matters. These actions take place in varying degrees with different waters, and ordinarily there would be a much larger amount of chemical wasted with river water before than after subsidence, while occasionally the effect of eddies and the like may be so marked as to cause an actual reduction in the required amount of chemical with river water as compared with the same water after subsidence.

Taking all these points into consideration, it will be seen that the difficulties of determining the optimum amount of chemical are more marked in the case of river water than with plain subsided water. There is also a considerable reduction in the average amount of chemical required for the water after subsidence.

In the following table there are given the estimated average amounts of chemical (sulphate of alumina) required with the modified English system to prepare satisfactorily the different grades of water for filtration, when the chemical is applied to the river water and also to the plain subsided water, based on the data of these investigations.

Estimated Average Amounts of Required Chemical for Different Grades of Water in the Modified English System.

River Water.		Subsided Water.	
Suspended Matter. Parts per Million.	Chemical Required Grains per Gallon.	Suspended Matter. Parts per Million.	Chemical Required Grains per Gallon.
100	1.50	75	1.30
125	1.60	100	1.60
150	1.70	125	1.80
175	1.80	150	2.00
200	1.95	175	2.10
300	2.25	200	2.20
400	2.50	300	2.45
500	2.80	400	2.75
600	3 05	.....	.....
750	3.40	.....	.....
1,000	4.00	.....	.....
1,200	4.75	.....	.....

Margin of Alkalinity with above Amounts of Chemical.—The available evidence shows that, assisted by the possible stopping of the river water pumps, there is no probability of getting more than 400 parts of suspended matter in the subsided water; and with a minimum of 20 parts of alkalinity in the water there is no likelihood of getting undecomposed chemical into the filtered water.

Relative to the river water the available data indicate that it would never be necessary to treat a water containing more than 1,200 parts of suspended matter, and only rarely as much as 1,000 parts. On a few days in the year, aggregating probably not more than five, it would apparently be necessary on account of inadequate alkalinity to add less chemical than would be required to reduce the suspended matter to 50 parts. This would be practicable and satisfactory, owing to the aid which at such times would be received from the capacity of the sand layer to store clay.

Annual Average Amount of Chemical Required.— It is estimated that the average amount of chemical which would have been used in connection with the modified English system, on the 134 days of 1898 when such treatment would have been required, would be 2.70 grains per gallon in the case of river water and 1.50 grains per gallon in the case of subsided water. These figures correspond to an annual average of 0.95 and 0.55 grain per gallon for river water and subsided water, respectively.

Influence upon Quality of Effluent.—The only essential point of difference in this respect between the two methods of application of chemical refers to the adaptability of the effluents for boiler purposes. Were the chemical applied to the river water the increase in calcium sulphate in the effluent would be greater by the proportion stated above. This is of course undesirable, but experience indicates that the effluent would be satisfactory for this line of use.

Conclusions.

Taking all the factors into consideration, the available evidence indicates that under the local conditions it would be somewhat more economical and convenient, and therefore more advantageous, to apply the chemical in the modified system before the entrance of the river water into the subsiding reservoirs. It is true that this would make the management of a plant more difficult of the two procedures considered; but with any procedure skilled and competent men would have to be placed in charge in order to insure satisfactory results. And the effluent would be slightly less desirable, but still satisfactory, for boiler purposes.

In connection with this decision it is to be clearly borne in mind that it is necessary to give considerable weight to the

influence of local conditions where the topography of available purification sites makes the construction of an adequate plant expensive and difficult to accomplish without separation into several isolated portions. Under different topographical conditions, and with the same river water, it is probable that this decision would be reversed to advantage, as its economy in many instances would be very small and incommensurate with the increased difficulties of operation and the undesirability of using the larger quantities of chemical necessitated by the application to the unsubsided river water.

THE EFFICIENCY AND ECONOMY OF THE FILTERS IN THE MODIFIED ENGLISH SYSTEM.

Quality of Effluent.—With filters of good construction and intelligent operation of the entire system, experience shows that the quality of the effluent, judged by the best standards of the present time, would be perfectly satisfactory with respect to the removal of bacteria, organic matter, and the minute clay particles.

Relative to the satisfactory bacterial efficiency obtained from filters Nos. 16 and 17, this is shown by the following average results from August 15, one week after the filters were put in operation, through September 24, when filter No. 17 was permanently stopped.

River water	10,200	Bacteria per Cubic Centimeter	
Subsided water	2,100	"	"
Effluent of filter No. 16	41	"	"
Effluent of filter No. 17	32	"	"
Bacterial efficiency of filters alone		No. 16	98.0
		No. 17	98.5
Bacterial efficiency of subsidence and filters		No. 16	99.6
		No. 17	99.7

In the case of filter No. 16 the total average bacterial results from August 15 to December 13, when it was permanently stopped, are as follows:

River water	18,300	Bacteria per Cubic	Centimeter.
Subsided water	5,000	"	"
Effluent of filter No. 16	55	"	"

The above data correspond to bacterial efficiencies of 98.9 and 99.7 when computed from the subsided water and river water, respectively.

The modifications stated would not necessarily remove entirely the possibility of deterioration in the quality of the effluent, due to disturbance of the surface of the sand layer by animal life. As stated in Chapter V, it is believed that this difficulty would be practically manageable as a rule by the judicious use of sufficiently fine screens.

During freshets there would be a marked increase at times in the sulphate of lime and carbonic acid in the effluent. But from the evidence available, there is no reason to believe that these changes would be seriously detrimental, although undesirable, as the effluent apparently at such times would be practically as good for boiler purposes as the river water at times of very low water in the river.

Elements of Cost of Construction and Operation. — Experience showed that 36 inches in thickness of the fine Coney Island sand, in an unwashed condition, would give satisfactory results. A depth of four feet of water above the original sand surface was satisfactory, and the loss of head could be carried to this point (4 feet) provided no surface disturbances occurred. Negative heads are impracticable.

With a satisfactory and adequate treatment of the river water when muddy, complications from deep penetration of clay into the sand layer would not arise with rates from 3 to 4

million gallons per acre daily. The same was found to be true with a rate of 5 million gallons, but the indications were that the suspended clay during the latter part of prolonged rises in the river should perhaps be kept as low as 40 parts per million, rather than 50 parts per million, as could be safely handled with somewhat lower rates and thicker sand layers.

To some it might seem more advisable to reduce the number of days and perhaps, to a slight degree, the actual rate of application of chemical by taking more advantage of the storage capacity of the filters through thicker sand layers and lower rates of filtration. At some places it is quite likely that local conditions would make such a procedure advisable. But at Cincinnati the available evidence clearly indicates that such steps would not be wise for the following principal reasons:

1. Owing to the fact that it is impracticable, by increasing the thickness of the sand layer or decreasing the rate of filtration, to obviate the use of a chemical at times of heavy freshets, it is not possible in this modified system, even if the capacity of the filters to store clay were materially increased, to do away with the cost of skilled supervision or the undesirability of comparatively large amounts of chemical during very turbid water in the river.

2. While it is cheaper and more logical, upon general principles, to make a preliminary treatment supplementary to subsidence for about one third of the year sufficient to allow filtration proper to be conducted as satisfactorily and as economically as would be the case for two thirds of the year in the absence of such treatment; it is especially so at Cincinnati, where the topography of the ground makes filter-construction unusually expensive, and where in a hilly country it is very

difficult to find suitable locations in one place or even closely adjoining places for a plant of 80 million gallons capacity.

The indications are that a net rate of three million gallons per acre daily could be safely depended upon from open English filters of this system. Were it not for the complications during cold weather in scraping, it is believed that materially higher net rates could be obtained. Whether it would be wiser to cover the filters or extend the size of the plant to meet future requirements is an open question, and should be settled by practical experience.

The thickness of the sand layer removed at a single scraping ranged from 0.75 to 1.0 inch. The volume of sand removed per million gallons of effluent is estimated at about 1.75 cubic yards.

According to the available data, it is estimated that, with actual rates of from about 4 to 5 million gallons per acre daily, the number of scrapings per annum would be from about 15 to 20, respectively.

The regular procedures at times of scraping, with no settling of the water above the sand and with no reduction in the rate of filtration upon the resumption of filtration, was satisfactory.

During these portions of the year, aggregating about 4.5 months, when the river water contained less than from 100 to 125 parts per million of suspended matter, it would be advantageous and economical as a rule to apply the river water directly to the filters, without preliminary subsidence. By this means the capacity of the filters to retain clay at and near the surface of the sand layer would be increased, due to the organic matter present in the river water when fairly clear.

For other important points under this topic reference is made to the corresponding portion of Chapter V, pages 240 to 241, so

far as they are not affected by the presence of excessive amounts of clay in the applied water.

NECESSARY SUPERVISION AND ATTENTION REQUIRED FOR THE OPERATION OF THIS SYSTEM.

It would be a much more difficult undertaking to operate a modified English system of purification than an English system applicable for the work for which it was constructed. The reason of this lies in the judgment which would be required to know when and how much chemical should be applied to the water. Safety and economy demand that this system should be in charge of men of adequate training and experience in this line of work, with sufficient attendants and a laboratory force to provide the necessary analytical data as promptly as possible.

Without such supervision and attention the citizens would have no surety against gross mismanagement and failure of the plant at times of heavy freshets in the river.

FINAL CONCLUSIONS.

The evidence shows that the modified English system of purification is applicable to the Ohio River water at Cincinnati, based on the satisfactory clarification and purification of the water. It would, however, be very much more difficult to operate, and somewhat more expensive, than is understood to be the case with those purification works of the English method now in use at various cities.

CHAPTER VIII.

Description of the Operation of the American System of Purification receiving Plain Subsided Water, and a Summary of the Principal Results accomplished Therewith.

On August 17, 1898, the available evidence indicated clearly that a satisfactory solution of the local problem would involve a decision between the modified English method and the American method of purification. The former would involve the application of chemical only at times of very turbid water, and the filtration of the water after an interval of subsidence at a comparatively slow rate through filters of the English type. In the case of the American method, coagulant at all times would be applied; and the water, after such treatment and at interval for coagulation and sedimentation, would be passed through filters of the American type at a very high rate as compared with that of the English filters.

In the decision between these two methods or systems of purification the deciding factor would be apparently one of cost, there being no apparent reasons why either method could not be made under proper supervision to give equally satisfactory results, so far as the quality of the effluent was concerned.

As the evidence then stood, this decision would have to be based on previous experiences elsewhere so far as the American method was concerned, or on bottle experiments made in the

laboratory here. Neither of these solutions seemed adequate for a decision in regard to a system of the magnitude necessitated here, the former on account of the difference in the character of the water, and the latter because of the lack of data by which to interpret satisfactorily in a practical way the results of coagulation in small bottles.

This situation was outlined to you in a special report dated August 17, 1898, in which it was recommended that a four-foot filter of the American type be installed, and that suitable chemical devices and coagulating basins should be arranged in connection therewith. In order to provide a sufficient quantity of subsided water for the operation of this new filter, it was necessary to stop permanently a number of the original filters, as previously stated.

These recommendations having been approved by you and by the Board of Trustees on August 19, 1898, work to this end was at once commenced. The system, including suitable devices for the application of chemical, three basins for the coagulation and partial clarification of the water by sedimentation, and a four-foot filter of the American type, constructed by and purchased from the O. H. Jewell Filter Company of Chicago, Ill., was completed by September 14, 1898, and was put in operation on the afternoon of that day.

Detailed descriptions of these devices were presented in Chapter II, pages 79 to 92, and there will be presented here a complete account of the manner of operation of this system, with summaries of the results accomplished therewith.

Before entering into these matters it will be well to present briefly the leading problems for the solution of which this system was operated.

1. Essentially the operation of this system was for the purpose of determining as closely as practicable the optimum

amount of chemical necessary to use for satisfactory purification of the Ohio River water at Cincinnati, after plain subsidence from two to three days.

The conditions of operation would apparently affect this determination; and, accordingly, the solution of the problems stated below became associated, if not fundamental, factors of importance in the decision as to the optimum amount of chemical. These factors were mainly as follows:

2. The most efficient period of coagulation and supplementary sedimentation for the satisfactory purification of Ohio River water at Cincinnati, after plain subsidence.

3. The most efficient sand layer, both as regards size of sand grain and thickness for satisfactory filtration of the properly prepared water.

4. The most practicable rate of filtration.

Other factors closely allied with these and incidental to the operation of the various parts of the system were naturally given due attention, and are presented in connection with those points which they most vitally affected. In the review of the operation of this system, however, it must be borne in mind that the solution of the above four points was the keynote of all operations; and that very often actual operations were carried on that were far removed from what was believed to be the most satisfactory, from a practical standpoint, in order to establish clearly limiting points in connection with these problems.

THE GENERAL METHOD OF OPERATION OF THE AMERICAN SYSTEM.

Practically speaking, the American system is composed of three main divisions, each independent of the others, but satisfactory operations of all being essential for the successful

operation of the system. These portions may be classified as follows:

1. The devices for the preparation and application of the chemical.

2. The basins in which coagulation and partial clarification of the water by subsidence takes place.

3. The filter through which the coagulated and partially clarified water is passed as a last step in the process.

Viewing the system as a whole, the water to be purified is first treated with the desired amount of chemical (applied in the form of a dilute solution) and it is then passed through the coagulating basins. In these basins the decomposed coagulant aggregates the clay particles and other matters, and when any of the aggregated particles reach a sufficiently great subsiding value they settle out. After passing through the basins, the water, in which all of the suspended matters present are more or less completely aggregated into relatively large particles, is passed on to a bed of sand. The latter acts as a strainer and removes the remaining coagulated particles, leaving the effluent clear and practically free of such matters, including bacteria.

The detailed operation of these portions is next presented.

OPERATION OF THE CHEMICAL DEVICES.

Kind of Chemical used. — As the most available chemical at that time for use in the coagulation of waters of this type, sulphate of alumina was employed in connection with these tests; but, as previously explained in Chapter VI, page 245, a different chemical could be readily substituted if found superior. In all, four different lots of this chemical were used, analyses of which have been presented in Chapter VI, page 246.

Those lots were used as follows:

Lot No. 1. September 14 to November 4.
Lot No. 2. November 4 to December 7.
Lot No. 3. December 7 to January 11.
Lot No. 4. January 11 to January 25.

From December 7 to 13 a small lot of commercial alum crystals was used, the third lot of sulphate of alumina not having been received. These crystals contained about 10.70 per cent of available aluminum.

Preparation of Chemical Solutions.—The chemical solutions were prepared in two wooden tanks, each holding 400 pounds of water, and normally solutions of one per cent in strength were used. Before preparing a new solution the tank was drained and cleaned, and four pounds of the chemical were then placed in a wooden box with a perforated bottom at the top of the tank. Filtered water was discharged on to the chemical in the box and allowed to drain into the tank. In this manner the chemical was dissolved during the filling of the tank, and no difficulty was found in making one per cent solutions in this manner when filling the tank in about forty-five minutes.

Application of the Chemical Solution.—The two tanks were used alternately for the preparation of the solutions and for a supply tank furnishing the solution applied to the water. From the supply tank the solution fed into a small copper tank, the level in which was maintained automatically by a float valve. The solution in the supply tank was stirred every half hour. Taps were provided at the bottom of this copper regulating tank, through which the solution was discharged into funnels on the end of lead pipes. These lead pipes connected, respectively, with the inlet water pipes to

basins F, G, H, and filter No. 20, and the solution was applied at such points as desired.

Regulation of Application of Chemical.—The rate of applying the chemical was regulated by means of the discharge pet cocks on the copper regulating tank, quantitative measurement of the rate of flow per minute being used as a guide. In determining the rate at which to apply the chemical solution to give the desired quantity of chemical, the quantity of water being handled was learned from the rate of flow of the effluent from filter No. 20, this being the only meter on the system.

OPERATION OF THE COAGULATING AND SUPPLEMENTARY SUBSIDING BASINS.

Normally the valve on the inlet pipe of the subsiding basins was left wide open, and the level of the water was regulated by the level in the regulating tank installed in connection with the English filters. Plain subsided water could be admitted to either basins F or G as desired, and after October 8 water could be admitted at any one of three points in basin H.

Period of Coagulation.—By the above arrangements average periods of coagulation and of sedimentation of 0, 0.5, 1.0, 2.5, 4.0, 4.5, and 6.0 hours could be obtained at the normal rate of flow. In these investigations, however, the only periods used regularly were 0.5, 2.5, and 6.0 hours. The actual periods of coagulation ranged from about 50 to about 150 per cent of the average period, which was computed from the capacity of the basins and the rate of flow of the water.

Changing of Water in the Basins.—As most of the operations of this system were conducted with the view to illustrate a certain point, or to establish a certain limit, it was very essential to make most of the runs of the filters under known conditions in regard to the treatment of the plain subsided water. On

this account it was customary to run the effluent from basin H into the sewer for about 0.5 hour more than the nominal period of displacement in use when increasing the period of subsidence or the quantity of chemical. To decrease the quantity of chemical or the period of subsidence, it was customary to drain and clean all basins, refill with untreated water, and then run to the sewer for 0.5 hour more than the nominal period of subsidence in use before applying the water to the filter. This last procedure was employed in order to avoid complications due to the possible presence of previously applied coagulant.

Draining the Basins.—Two 1.5-inch drain pipes were connected with each basin for this purpose.

Cleaning the Basins.—The basins were cleaned with a broom aided by a stream of water from a hose, except during the coldest weather, when it was necessary to hoist the ice and deposited material out of the tanks in buckets.

OPERATION OF THE FILTER.

As the operation of filters of the American type has been very fully described in other reports, it will only be briefly referred to here.

Filling the Filter.—After washing, the space above the sand layer was first filled with chemically treated water, the flow of which was regulated by the inlet valve. As soon as the tank was full (two to three minutes) the outlet valve was opened and filtration begun at the normal rate.

Filtration.—The rate of filtration was regulated by the outlet valve from meter readings at frequent intervals (at least every half hour), and was maintained at as nearly a constant rate as practicable. Three different forms of automatic controllers constructed by the Jewell Company were tried at different times. But under the conditions of operation with

a relatively low pressure in the outlet pipe none of these devices proved adequate. This failure seemed to be mainly due to the fact that the friction in the moving parts of these devices amounted to several feet in head, and the devices in consequence were intermittent in their action or else did not act at all.

As was presented in the premises of this chapter, the nominal rate of filtration was varied from time to time for different runs, but in all cases it was the custom to maintain as nearly as practicable the same rate of filtration from the time the outlet was first opened, following a wash of the filter, until it was closed again preparatory to washing again.

Decision to Wash the Filter.—Except in the case of some special runs, it was customary to continue filtration until the loss of head reached 10 feet, providing the water did not become materially less satisfactory in appearance than it was at the start of the run. As noted above, several runs were made in order to establish certain limitations, on which the effluent was of an unsatisfactory character from the beginning of a run, and in these cases filtration was only continued long enough to collect the required data.

Surface Agitation.—Surface agitation was tried at various times under varying conditions, but was not employed as a regular practice during these tests. This operation consisted essentially in breaking up the coating on the surface of the sand layer by dragging the chains on the end of the agitator teeth over the surface. While this was being done the outlet was closed and filtration was stopped. The effect of draining off the water above the sand layer during the stirring was tried at times, special siphons being used to remove the water to within two inches of the sand layer. As soon as the operation of agitation was complete the inlet was opened and the filter filled if it

had been drained. When the filter was full the outlet was opened and filtration was begun again. If the filter was not drained, the inlet and outlet were opened at the same time. When the water above the sand layer was not removed, about two minutes were sufficient to complete the operation. The time was somewhat longer when the water was drained off, owing to the size of the siphons, and was from four to five minutes.

Draining the Filter preparatory to Washing.—When it was decided to wash the filter, the inlet valve was closed, and the water above the edge of the inner tank (overflow in washing) was filtered out through the outlet.

Washing the Filter.—As soon as the water above the sand was drained down to the level of the top of the inner tank the outlet valve was closed and the inlet valve for wash water was opened. At the same time the agitator was set in motion with the rakes turning down into the sand. As soon as the rakes had reached their lowest point the downward motion was stopped, and they were revolved at the same level until the wash water, after passing up through the sand, contained no more heavy particles of coagulated material. The motion of the rakes was then reversed, and they were gradually drawn out of the sand layer, the flow of wash water being slowly checked as the rakes approached their upper position. When the rakes were raised to the highest point the agitator was stopped, the flow of wash water was completely shut off, and the filter was again ready for filling.

By the above procedure the sand layer was in all cases washed until the wash water was entirely free of coarse material, and practically clean. With the coarse sand this operation required about twenty minutes on an average; but when the fine sand layer was used it was found that it was not safe to

maintain as great a vertical velocity of the water as with the coarse sand. After several trials it was found that about 1.00 foot vertical velocity per minute was as high as could be used and avoid washing the sand out of the filter. Accordingly, a slightly lower rate than this was adopted and the time of washing was increased to about thirty minutes. On an average the vertical velocities of the wash water used in washing this filter with the coarse and fine sand layers were about 1.3 and 0.9 feet per minute, respectively, corresponding to approximately 0.7 and 0.5 cubic foot per square foot of surface of the sand layer per minute, or 330 and 235 million gallons per acre daily.

THE CONDITIONS OF ACTUAL OPERATION OF THE AMERICAN SYSTEM.

At the close of this chapter there is presented a table in which the leading results of operation of the American system are arranged and averaged by "runs" of the filter. A "run" included all of the operations of the system from the time the outlet was opened following a washing of the sand layer until it was again opened after the next wash. Immediately preceding the table there is an explanation of the quantities presented, and here there will be given for the better understanding of these results a brief outline of the leading points which were under study from time to time. For simplicity of description solely the operations have been divided into eleven different periods, and in the following sections the leading conditions of operation during each period are presented. Operations were begun with this system on September 14, 1898, and continued night and day without interruption through January 25, 1899, except that the plant was shut down from November 23, 12 P. M., to November 24, 12 P. M.

Period No. 1.

This period extended from the beginning of operation of this system on September 14 to September 18, 1898, and includes runs Nos. 1 to 5. It may be called the period of preparation of the sand layer. As the sand was first put in the filter it contained relatively high numbers of bacteria (32,900 per gram); but, on the other hand, it was very free of organic matter. Under these conditions the sand had two actions, both of which were detrimental to the character of the effluent, in that it did not seem to retain the coagulated material as well as after it had been in use for some time, and the bacteria on the sand were washed out during the process of filtration. During this period the suspended matters in the plain subsided water ranged from 10 to 21 and averaged 15 parts per million.

Period No. 2.

From September 18 to October 8 and from October 19 to 26, 1898, including runs Nos. 6 to 23 and 32 to 37, the operations were devoted to establishing, in so far as practicable, the minimum amount of chemical which could be used with very clear river water after plain subsidence, and the effect on this minimum quantity of different periods of coagulation. The rate of filtration was held normally at 120 million gallons per acre daily, and periods of 0.5, 2.5, and 6.0 hours of coagulation and subsidence were employed. In the plain subsided water the suspended matters ranged from 8 to 30 and averaged 13 parts per million.

Period No. 3.

From October 9 to 18, 1898, special studies were made of the effect of surface agitation on the quantitative and quali-

tative efficiencies of filtration. Runs Nos. 24 to 31 are included in this period, and on all of these runs the surface of the sand layer was agitated when the loss of head reached 10 feet. The process as employed during this period consisted simply in stopping filtration and dragging the chains at the end of the rake-arms over the surface of the sand by revolving the agitator twice to the right and then twice back to the left. There was no draining of the filter, and the operation required about two minutes.

During this period the suspended matters in the plain subsided water ranged from 6 to 21 and averaged 13 parts per million.

Period No. 4.

This period extended from October 27 to November 12, 1898, and includes runs Nos. 38 to 75. Operations were devoted to the same general problems as in Period No. 2 — that is, the effect of different periods of coagulation and subsidence on the minimum amount of chemical; but the amount of suspended matter in the plain subsided water was much higher, ranging from 25 to 120 and averaging 52 parts per million.

Period No. 5.

From November 13 to 19, 1898, the suspended matters in the plain subsided water were very high in amount, comparatively speaking, ranging from 68 to 150 and averaging 106 parts per million. Such waters require high amounts of chemical, and attention was directed on the twelve runs of this period (Nos. 76–88) to the relative value of equal amounts of chemical when applied previous to 6.0 and 0.5 hours of supplementary subsidence, respectively, and when divided between these two points of application.

Period No. 6.

The rate of filtration was the factor under consideration throughout the period which lasted from November 21 to December 4, 1898, and included runs Nos. 89 to 114. Essentially, the operations were with high rates, the range being from 120 to 170 million gallons per acre daily. In connection with this study the effect of different periods of coagulation on the efficiency of filtration at the various rates was made a contemporary study. The suspended matters in the plain subsided water were rather low, ranging from 18 to 57 and averaging 31 parts per million.

Period No. 7.

On December 6, 1898, the original layer of coarse sand was removed from the filter and replaced by 30 inches of fine sand from Coney Island. The period from December 6 to 9 was mainly one of cleaning this sand layer and preparing it for efficient filtration, though the general qualitative and quantitative efficiencies were made the nominal points of investigation. Runs Nos. 115 to 121 are included in this period, and the suspended solids in the plain subsided water were high most of the time, ranging from 14 to 158 and averaging 85 parts per million. On runs Nos. 116 to 118, inclusive, surface agitation, accompanied by draining off the water above the sand to within two inches of the sand layer, was employed. The time required for this operation was from four to five minutes.

Period No. 8.

This period extended from December 9 to 14, 1898, and includes runs Nos. 122 to 134. On December 9 the coarse sand was again put in the filter. It was frozen, however, and

several days were required to restore it to normal efficiency. All of the operations of this period were for the purpose of establishing, in so far as practicable, the minimum amount of chemical which could be satisfactorily employed with 6.0 hours of coagulation and sedimentation preceding filtration through the layer of coarse sand. The suspended solids in the plain subsided water ranged from 70 to 150 and averaged 91 parts per million.

Period No. 9.

This was really a continuation of Period No. 7, the 30 inches of fine sand having been replaced on December 14. The period extends to December 22, 1898, when the thickness of the layer was reduced, and includes runs Nos. 135 to 155. At the beginning of the period the sand layer was not as efficient as normally, owing to its slightly frozen condition when it was put in the tank. The operations were devoted to the determination of the minimum chemical with 6.0 hours' coagulation and sedimentation preceding filtration through 30 inches of fine sand. The minimum, maximum, and average suspended matters in the subsided water were 18, 170, and 43 parts per million, respectively.

Period No. 10.

On December 22, 1898, preceding run No. 156, the thickness of the sand layer was reduced to 15 inches. This period extends from December 22 to 24, and includes runs Nos. 156 to 158, all of which were made with a 15-inch layer of fine sand. The suspended solids in the plain subsided water ranged from 150 to 170 parts, with an average of 160 parts per million.

Period No. 11.

The balance of the operations with this system are included in this period, which extended from December 24, 1898, with run No. 159, to the close of the operations on January 25, 1899. On December 24 the thickness of the sand layer was increased to 20 inches by the addition of 5 inches more of fine sand, and this sand layer was used throughout the balance of the investigations.

Generally speaking, the operations were directed toward the establishment of the minimum chemical to be used with six hours of coagulation and sedimentation and a 20-inch layer of fine sand, with the various grades of water handled. For short intervals special runs were made, for the purpose of illustrating the effect of shorter periods of coagulation, of different rates of filtration, and of divided application of the chemical.

On January 3, 4, 5, and 6 unsubsided river water, containing from 58 to 206 parts per million of suspended matters, was passed into the system. During this period the suspended matters in the water admitted to the system ranged from 47 to 206 and averaged 103 parts per million.

From December 17 to December 25 the numbers of bacteria in the subsided water were very high, due apparently to growths of a florescent form in the subsiding tanks. (See page 128.)

SUMMARIES OF THE RESULTS OF OPERATION OF THE AMERICAN SYSTEM.

In the following tables are presented summaries of all of the leading results of operation of the American system. The detailed results from which these averages were compiled are presented in Appendix III. A brief description of the

tables of summaries presented and the methods of computation employed is next given.

Table No. 1.

In this table (pages 316 to 333) are presented all of the leading results of the operation of the American system, arranged and averaged by "runs." A run, as described above, includes all of the operations from the time the outlet valve is first opened following a wash of the filter until it is again opened after the next succeeding wash.

For the purpose of establishing limiting conditions it was often found advisable to make trial runs under known adverse conditions. At times these runs were carried to their normal end (failure of effluent or exhaustion of working head), but for the most part they were only continued to a sufficient length to establish the point in question. Those short runs made under .these conditions are starred in the table. The data are as follows:

Beginning of Run.—The date and hour of the beginning of the run (first opening of outlet after preceding wash) are given. This corresponds to the end of the preceding run.

Period of Service.—This is the time during which the filter was furnishing filtered water on this run.

Period of Wash.—Under this heading is included all the time occupied in washing the sand layer of the filter, and filling the filter preparatory to filtration on the next run. In the absence of any delay this includes all of the time from the closing of the outlet (cessation of filtration) to the opening of the outlet (beginning of filtration). This also includes the period of surface agitation when employed,

Quantities of Water.—The actual amount of water filtered on each run, and used for washing the filter, are each given in

cubic feet. The former was obtained from meter measurement and the latter from gage readings on the wash-water supply tank.

Percentage of Wash Water.—The percentage of the water filtered on each regular run which was used for washing the sand layer is given. During the operations there were several runs made for special purposes which were not continued to their normal end. In such cases the actual amount of wash water used is recorded, but the percentage is not given.

Average Rate of Filtration.—The average rate of filtration in cubic feet per minute was determined by dividing the total quantity of filtered water by the period of service in minutes. Conversion of this rate into the corresponding number of million gallons per acre per day was made on the basis that 100 million gallons per acre per day was equivalent to 2.677 cubic feet per minute.

Applied Chemical.—Under this heading is given the average amount of chemical in grains per gallon which was applied to the water filtered in each run. This was determined from the average rate of application of the chemical (average of hourly readings) and the average rate of filtration. In making these averages the application was computed to have taken place before the water reached the filter by a period equal to the average period of coagulation.

At times chemical was applied at two places at once. This procedure when adopted regularly took place in connection with six hours' coagulation and subsidence, the first application being made at the beginning of this period, and the second one as the water left the subsiding basins and passed on to the filter. Both amounts are recorded in the order of their application.

Period of Coagulation.—As explained above, different tanks and parts of tanks were used at various times for the purpose

of coagulation and sedimentation of the water after the application of the chemical and before it reached the filter. The average time occupied by the water in passing through these basins is recorded. It is to be noted that the actual period varied from 50 to 150 per cent of the average time, some of the water appearing at the outlet quite quickly and some lagging behind for a considerable period. The average period was found to correspond very closely with the capacity of the tank divided by the rate of flow.

Suspended Matter in the Plain Subsided Water.—The average weight of suspended matters in the plain subsided water as it was delivered to the system was determined for each run by finding the average amount of suspended matter which was in the plain subsided water during a period equal to the period of service, but which began and ended before filtration began and ended, by a period equal to the average period of coagulation.

Suspended Matters in the Applied Water.—Under this heading are presented averages of determinations made every eight hours of the amount of suspended matters in the water as it left the subsiding basins and passed upon the filter. These determinations were not made from September 18 to October 27, 1898, on account of the uniform and comparatively clear character of the subsided water.

Degree of Clearness.—The appearance of the effluent in degrees of clearness are recorded on the same basis as was explained in Chapter IV, page 158. It is only necessary to repeat that an effluent of degrees Nos. 1, 2, or 3 was satisfactory in appearance, and degrees Nos. 4 or 5 unsatisfactory.

Bacteria in the Subsided Water.—The bacteria per cubic centimeter in the water delivered to the system which was filtered on each run are given, the averages having been

determined in the same manner as the suspended matters, as explained on the last page.

Bacteria in the Effluent.—Under this heading are given the maximum, minimum, and average number of bacteria in the effluent. In determining the average, wherever two or more samples were collected within half an hour on the same run, an average of them was taken and used as a single determination in obtaining an average for the run. Wherever the character of the effluent suddenly failed, and the filter was immediately shut down and washed, the result of examination of the sample taken at the time of such failure was recorded (see Appendix III), but was not included in the average.

Average Bacterial Efficiency.—These results were determined in the usual manner, and show the percentages which the differences between the bacteria in the water delivered to the system (plain subsided water) and in the effluent were of those in the plain subsided water.

Table No. 2.

In this table (page 334) are presented monthly averages of all results of chemical and bacterial analyses of the effluent of the American system. The individual bacterial analyses will be found in Appendix III, and the results have all been sufficiently explained in Chapter IV (page 157), and do not require further comment here.

TABLE No. 1.—*Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Alumina in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1898.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
1	Sept. 14	2:47 PM	17.32	0.50	3,290	136	4.1	3.17	118	0.50	2.5
2	" 15	9:06 AM	15.48	0.56	2,898	212	7.3	3.12	116	0.60	2.5
3	" 16	1:10 AM	26.60	0.48	5,033	358	6.9	3.16	118	0.60	2.5
4	" 17	4:15 AM	24.87	0.70	4,863	82	1.8	3.33	124	0.60	2.5
5	" 18	5:49 AM	25.37	0.48	4,735	110	2.3	3.11	116	0.60	2.5
6	" 19	7:40 AM	28.90	0.58	5,417	125	2.3	3.12	116	0.60	2.5
7	" 20	1:14 PM	26.37	0.53	5,031	163	3.2	3.18	119	0.76	2.5
8	" 21	4:18 PM	23.42	0.45	4,557	112	2.5	3.24	121	0.60	2.5
9	" 22	4:10 PM	20.17	0.63	3,840	196	5.1	3.18	119	0.60	2.5
10	" 23	5:45 PM	19.53	0.40	3,807	142	3.7	3.24	121	0.62	6.0
11	" 24	1:41 PM	32.45	0.32	6,249	112	1.8	3.20	120	0.61	6.0
12	" 25	10:27 PM	31.72	0.36	5,865	109	1.9	3.08	115	0.79	6.0
13	" 27	6:32 AM	32.71	0.32	6,203	106	1.7	3.16	117	0.79	6.0
14	" 28	7:37 PM	22.92	0.28	4,405	106	2.4	3.21	120	1.20	2.5
15	" 29	10:27 PM	23.75	0.30	4,515	120	2.7	3.16	118	1.20	2.5
16	" 30	10:30 PM	23.67	0.30	4,541	112	2.5	3.19	119	1.20	2.5
17	Oct. 1	10:28 PM	20.73	0.30	3,961	101	2.5	3.18	119	1.20	2.5
18	" 2	7:30 PM	24.67	0.30	4,646	109	1 9	3.13	117	1.16	2.5
19	" 3	8:28 PM	24.83	0.37	4,818	120	2.5	3.24	121	0.79	2.5
20	" 4	9:40 PM	24.25	0.35	4,631	119	2.6	3.18	119	0.78	2.5
21	" 5	10:28 PM	26.67	0.33	5,057	120	2.4	3.16	118	1.58	2.5
22	" 7	1:28 AM	19.70	0.25	3,874	109	2.8	3.27	122	1.75	2.5
23	" 8	2:10 PM	19.67	0.35	3,788	109	2.9	3.21	120	2.05	2.5
24	" 9	10:11 AM	28.90	0.28	5,580	104	1.9	3.22	120	1.21	2.5
25	" 10	7:08 PM	24.35	0.35	4,690	111	2.4	3.21	120	0 84	2.5
26	" 12	2:50 AM	35.16	0.43	6,899	120	1.7	3.22	120	1.20	6.0

and of the Efficiency of the American System.

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
10	9	3	1,600	23,600	1,500	9,200	—475.0	1	
21	13	2	2,900	7,200	1,100	4,300	—48.3	2	
17	16	1	1,700	4,700	1,200	2,600	-53.0	3	
11	15	1	2,800	4,000	1,100	1,800	35.7	4	
17	14	1	2,200	2,200	550	750	65.9	5	
30	....	1	2,000	1,200	120	300	85.0	6	
11	....	1	1,400	600	95	250	82.1	7	
10	....	1	1,200	400	65	170	85.8	8	
16	....	1	5,000	300	95	150	97.0	9	
27	....	1	4,100	550	140	220	94.6	10	
26	....	1	11,200	650	110	280	97.5	11	
21	....	1	1,600	475	18	100	93.7	12	
15	....	1	1,600	200	28	70	95.6	13	
22	...	1	1,800	150	12	50	97.2	14	
26	....	1	1,700	190	16	75	95.6	15	
19	....	1	1,300	425	70	200	84.6	16	
9	....	1	1,000	200	55	110	89.0	17	
8	....	1	450	325	11	60	86.7	18	
7	....	1	2,000	170	12	43	97.8	19	
8	....	1	1,000	110	7	29	97.1	20	
15	....	1	13,400	100	7	27	99.8	21	
13	....	1	3,900	100	4	15	99.6	22	
15	....	1	3,800	75	5	29	99.2	23	
7	....	1	4,100	100	9	26	99.4	24	Agitated Oct. 10, 2:30 PM.
7	....	1	2,700	65	11	27	99.0	25	Agitated Oct. 11, 7:00 PM.
6	....	1	1,300	50	5	13	99.0	26	Agitated Oct. 13, 1:01 PM.

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. — Hours.		Quantities of Water. — Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Aluminn in Grains per Gallon of Filtered Water.	Period of Coagulation. — Hours.
	Date—1896.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
27	Oct. 13	9:25 PM	33.02	0.40	6,427	93	1.4	3.24	121	0.81	6.0
28	" 15	11:50 AM	16.58	0.35	3,129	98	3.1	3.15	118	0.80	0.5
29	" 16	7:19 AM	23.31	0.35	4,452	106	2.4	3.19	119	0.78	2.5
30	" 17	9:25 AM	22.10	0.38	4,260	104	2.4	3.14	117	1.00	2.0
31	" 18	11:25 AM	18.26	0.40	3,515	109	3.1	3.21	120	1.00	0.5
32	" 19	1:48 PM	33.15	0.43	6,452	98	1.5	3.24	121	1.00	6.0
33	" 21	6:53 AM	30.00	0.62	5,799	180	2.2	3.21	120	0.81	6.0
34	" 22	7:10 PM	25.71	0.62	5,002	131	2.6	3.25	121	0.81	0.5
35	" 24	1:40 AM	18.26	0.40	3,471	106	3.1	3.17	118	0.81	0.5
36	" 24	9:26 PM	20.26	0.43	3,947	125	3.2	3.24	121	0.60	0.5
37	" 26	1:12 AM	25.30	0.35	4,991	109	2.2	3.28	123	0.60	6.0
38*	" 27	10:12 AM	2.05	0.30	379	98	....	3.09	115	0.72	0.5
39*	" 27	12:43 PM	2.01	0.20	371	104	....	3.08	115	0.72	0.5
40*	" 27	3:42 PM	2.00	0.30	368	82	....	3.07	115	1.01	0.5
41*	" 27	6:30 PM	2.00	0.50	384	120	....	3.20	120	1 30	0.5
42*	" 28	4:05 AM	7.00	0.35	1,449	93	....	3.45	128	0.70	6.0
43	" 28	11:26 AM	12.07	0.53	2,450	98	4 0	3.38	126	1.00	6.0
44	" 29	12:02 AM	35.95	0.35	6,863	120	1.7	3.18	119	2.00	6.0
45	" 30	7:30 PM	12.73	0.30	2,402	125	5.2	3 24	121	2.00	0.5
46	" 31	11:44 AM	15.59	0.33	3,017	142	4.7	3.22	120	2.00	2.5
47	Nov. 1	10:39 AM	29.17	0.30	5,753	125	2.2	3.28	123	1.42	6 0
48	" 2	9:30 PM	3.60	0.45	698	125	17.9	3.28	123	1.25	0.5
49*	" 3	5:02 AM	5.97	0.27	1,194	115	....	3.33	124	1 25	2.5
50*	" 3	4:03 PM	2.03	0.47	401	115	....	3.30	123	1 25	6.0
51*	" 3	12:00 PM	2.00	0.33	392	104	....	3.27	122	1.26	0.5
52*	" 4	5:00 AM	2.00	0.32	373	120	....	3.11	116	1.25	2.5

* Short run.

and of the Efficiency of the American System – (Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
16	....	1	1,900	80	7	32	98.3	27	Agitated Oct, 15, 4:00 AM.
17	....	1	1,000	55	2	19	98.1	28	Agitated Oct. 16, 4:10 AM.
20	....	1	2,000	70	20	32	98.4	29	Agitated Oct. 18, 7:00 AM.
21	....	1	1,900	220	6	25	98.7	30	Agitated Oct. 19, 3:25 AM and 6:00 AM.
13	....	1	2,800	70	8	19	99.3	31	
10	....	1	7,400	85	6	37	99.5	32	
12	....	1	2,800	120	15	35	98.7	33	
12	....	1	1,200	800	5	66	94.5	34	
14	....	1	1,200	29	8	13	98.9	35	
16	....	1	800	26	9	15	98.1	36	
13	....	1	1,900	100	22	41	97.8	37	
55	....	1	4,900	110	85	100	98.0	38*	
55	....	1	3,300	190	65	130	96.1	39*	Stirred water on filter during filtration.
54	...	1	3,300	75	46	50	98.5	40*	
52	38	1	2,800	55	9	37	98.7	41*	
48	33	1	2,800	90	9	65	97.7	42*	
45	....	1	2,500	50	9	20	99.2	43	
120	....	1	6,300	90	17	43	99.3	44	
114	....	3	5,300	350	19	180	96.6	45	
80	....	1	5,200	275	9	100	98.1	46	
73	....	1	4,400	100	11	32	99.3	47	
72	....	5	3,700	300	90	190	94.9	48	
76	....	3	3,200	170	33	80	97.5	49*	
77	....	3	2,500	130	36	90	96.4	50*	
78	....	5	2,700	220	140	190	93.0	51*	
69	....	4	4,300	230	65	160	96.3	52*	

*Short run.

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Alumina in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1898.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
53*	Nov. 4	2:00 PM	2.00	0.33	364	103	....	3.03	113	1.00	6.0
54*	" 4	4:20 PM	7.67	0.47	1,500	120	....	3.25	121	1.29	6.0
55	" 5	12:28 AM	34.79	0.31	6,668	175	2.6	3.19	119	1.52	6.0
56	" 6	3:57 PM	15.13	0.37	2,919	164	5.6	3.22	120	1.51	0.5
57	" 7	10:00 AM	12.25	0.30	2,408	147	6.1	3.28	122	1.51	2.5
58*	" 8	1:35 AM	2.08	0.17	398	104	....	3.20	120	1.51	0.5
59*	" 8	4:14 AM	2.10	0.20	399	104	....	3.17	118	1.26	0.5
60*	" 8	6:55 AM	2.05	0.25	389	87	....	3.16	118	1.00	0.5
61*	" 8	9:31 AM	2.00	0.33	384	109	....	3.20	120	0.75	0.5
62*	" 8	2:30 PM	2.00	0.28	384	104	....	3.20	120	0.74	2.5
63*	" 8	5:30 PM	2.00	0.27	292	87	....	3.27	122	1.01	2.5
64*	" 9	2:35 AM	7.02	0.22	1,307	87	....	3.10	116	0.62	6.0
65*	" 9	10:50 AM	7.00	0.35	1,371	93	....	3.25	121	1.01	6.0
66*	" 9	6:10 PM	7.08	0.28	1,368	115	....	3.22	120	1.00	6.0
67	" 10	1:37 AM	24.45	0.33	4,630	164	3.5	3.16	118	1.26	6.0
68*	" 11	6:50 AM	0.33	0.17	66	60	....	3.03	113	1.26	0.5
69*	" 11	10:00 AM	2.00	0.18	379	82	....	3.16	118	1.27	2.5
70*	" 11	5:04 PM	7.02	0.28	1,385	136	....	3.28	123	1.27	6.0
71*	" 12	12:27 AM	2.13	0.24	407	93	....	3.15	118	1.52	6.0
72*	" 12	6:49 AM	0.58	0.20	112	82	....	3.22	120	1.50	0.5
73	" 12	8:00 AM	11.38	0.25	2,153	109	5.1	3.16	118	1.77	0.5
74*	" 12	8:00 PM	2.50	0.22	472	98	....	3.15	118	1.76	0.5
75	" 12	11:05 PM	7.97	0.32	1,490	153	10.3	3.12	117	2.02	0.5
76	" 13	7:39 AM	4.83	0.27	968	125	12.9	3.33	124	2.50	0.5
77*	" 13	7:14 PM	0.50	....	86	....	....	2.87	107	2.26	6.0
78*	" 13	7:44 PM	6.55	0.27	1,268	120	....	3.22	120	{2.26 {0.75	6.0
79	" 14	2:40 AM	5.45	0.23	1,046	125	11.9	3.20	120	{1.50 {0.82	6.0

and of the Efficiency of the American System—(Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
42	....	4	3,400	170	70	150	95.6	53*	
42	....	2	3,400	110	16	90	97.4	54*	
42	....	1	3,400	110	....	20	99.4	55	
32	30	2	1,700	170	12	80	95.3	56	
29	22	1	1,900	95	7	34	98.2	57	
25	....	2	1,500	90	13	55	96.3	58*	
25	....	1	1,500	55	14	38	97.5	59*	
25	....	1	2,300	30	6	21	99.1	60*	
25	....	3	3,100	125	40	70	97.7	61*	
55	30	3	3,100	275	70	170	94.5	62*	
53	38	2	8,700	220	150	180	97.9	63*	
46	....	5	11,400	2,200	300	1,100	90.3	64*	
46	...	4	9,500	1,200	120	800	91.6	65*	
40	33	2	7,100	600	100	250	96.5	66*	
44	27	1	7,900	425	55	190	97.5	67	
42	....	4	13,200	650	600	600	95.5	68*	
40	....	1	14,400	200	75	120	99.2	69*	
46	25	1	6,300	275	34	140	97.8	70*	
47	16	1	7,700	180	44	70	99.1	71*	
47	...	3	7,700	500	150	300	96.1	72*	
40	....	1	6,800	375	65	180	97.4	73	
35	....	1	8,100	150	65	140	98.3	74*	
33	....	2	65,000	2,500	120	1,000	98.5	75	
150	106	1	56,000	2,100	325	800	98.6	76	
140	114	4	47,000	15,000	1,300	1,400	97.0	77*	
138	83	2	36,000	1,100	200	600	98.3	78*	
125	106	2	33,000	2,900	600	1,300	96.1	79	

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Alumina in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1898.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
80	Nov. 14	8:28 AM	3.97	0.33	727	98	13.5	3.28	123	{1.40 / 0.75}	6.0
81	" 14	2:30 PM	13.00	0.27	2,479	144	5.8	3.17	118	{2.26 / 0.75}	6.0
82*	" 15	9:17 AM	0.48	0.25	82	109	....	3.18	119	1.75	0.5
83	" 15	10:06 AM	4.10	0.33	761	120	15.8	3.24	121	2.02	0.5
84	" 15	8:44 PM	10.80	0.25	2,078	120	5.8	3.21	120	{1.50 / 0.47}	6.0
85	" 16	2:05 PM	35.17	0.28	6,733	131	1.9	3.19	119	2.54	6.0
86*	" 18	6:10 AM	3.57	0.20	691	104	....	3.22	120	3.02	0.5
87	" 18	4:21 PM	17.53	0.23	3,389	152	4.5	3.22	120	{2.54 / 0.50}	6.0
88	" 19	4:29 PM	32.85	0.42	6,367	152	2.4	3.23	121	2.88	6.0
89*	" 21	1:45 AM	7.75	0.23	1,567	93	....	3.35	125	2.50	6.0
90*	" 21	10:08 AM	5.87	0.30	1,452	131	....	4.12	154	2.52	4.5
91	" 21	7:05 PM	17.42	0.32	3,397	115	3.4	3.25	121	2.26	6.0
92	" 22	12:50 PM	25.50	0.35	4,911	103	2.1	3.15	118	2.08	6.0
93*	" 23	2:51 PM	7.90	0.33	2,156	87	....	4.54	170	1.86	4.5
94*	" 25	2:40 AM	5.83	0.33	1,487	136	....	4.24	158	1.75	4.5
95	" 25	8:50 AM	18.67	0.43	3,642	101	2.8	3.25	121	1.76	6.0
96*	" 26	4:15 AM	1.25	0.33	302	63	....	4.02	150	1.75	4.5
97*	" 26	5:50 AM	2.50	0.25	451	44	....	3.01	112	1.75	6.0
98*	" 26	9:15 AM	0.25	0.12	52	60	....	....	....	1.75	6.0
99	" 26	2:05 PM	9.42	0.38	2,488	109	4.4	4.39	164	2.02	4.5
100	" 26	11:53 PM	15.87	0.33	3,223	109	3.4	3.38	126	1.75	6.0
101	" 27	4:05 PM	6.92	0.23	1,829	103	5.6	4.40	164	1.75	4.5
102	" 28	5:05 AM	19.92	0.42	3,740	134	3.6	3.15	118	1.50	6.0
103*	" 29	8:05 AM	1.17	0.20	210	87	....	3.00	112	1.00	6.0
104*	" 29	3:20 PM	0.58	0.22	99	187	....	2.84	116	1.27	0.5
105*	" 29	10:30 PM	0.50	0.25	96	60	....	3.20	120	1.26	6.0
106	" 30	5:33 AM	22.45	0.33	4,311	153	3.6	3.21	120	1.40	6.0

and of the Efficiency of the American System—(Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
124	110	2	38,500	1,300	350	700	97.9	80	
120	42	1	35,000	800	13	150	99.6	81	
80	....	4	25,000	1,100	400	800	96.8	82*	
75	66	1	20,500	325	130	250	98.8	83	
68	42	1	20,200	400	49	110	99.5	84	
75	24	1	24,100	425	70	160	99.3	85	
106	77	1	25,200	350	150	230	99.1	86*	
102	23	1	20,800	425	19	70	99.7	87	
75	14	1	8,200	375	8	90	98.9	88	
57	16	1	7 400	230	19	65	99.1	89*	Stopped at 4.5 feet loss of head for special run.
58	16	1	7,100	120	4	21	99.7	90*	
47	19	1	6,200	110	11	48	99.2	91	
42	14	1	5,500	140	4	43	99.2	92	
43	24	1	6,700	70	2	14	99.8	93*	
41	21	1	7,000	27	6	13	99 8	94*	
43	17	1	4,100	65	8	22	99.5	95	
34	....	4	2,600	350	230	300	87.5	96*	Application of chemical irregular, due to failure to stir solution.
34	34	4	2,800	375	350	350	86.5	97*	
30	...	4	2,800	400	375	400	84.7	98*	
32	18	1	3,600	150	4	35	99.0	99	
86	17	1	3,000	70	9	42	98.6	100	
33	18	1	2,300	180	9	74	96.8	101	
27	15	1	3,900	250	11	88	97.7	102	
22	....	3	3,900	400	55	180	95.4	103*	
21	....	3	3,200	140	120	130	96.9	104*	
25	....	4	3,500	475	160	300	91.4	105*	
20	10	1	3,400	200	10	60	98.2	106	

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Aluminæ in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1898.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
107	Dec. 1	10:35 AM	18.92	0.25	3,652	109	3.0	3.22	120	1.50	6.0
108	" 2	5:57 AM	8.10	0.30	2,146	142	6.6	4.40	164	1.50	4.5
109	" 2	6:50 PM	10.17	0.40	1,955	115	5.9	3.20	120	1.50	0.5
110	" 3	5:25 AM	5.58	0.42	1,489	130	8.7	4.44	166	1.50	0.5
111	" 3	11:40 AM	9.58	0.55	1,810	130	7.2	3.14	117	1.50	0.1
112	" 3	9:48 PM	6.27	0.32	1,570	87	5.5	4.17	156	1.50	0.1
113	" 4	4:50 AM	12.75	0.50	2,381	114	4.8	3.11	116	1.26	0.5
114	" 4	6:10 PM	7.66	....	1,482	....	....	3.23	121	1.76	6.0
115	" 6	4:45 PM	9.25	0.37	1,780	106	6.0	3.21	120	1.25	6.0
116	" 7	8:34 AM	8.92	0.76	1,674	73	4.3	3.13	117	1.01	6.0
117	" 7	6.30 PM	9.64	0.61	1,818	52	2.9	3.15	118	1.00	6.0
118	" 8	4:50 AM	9.24	0.71	1,720	101	5.9	3.10	116	1.56	6.0
119[a]	" 8	9:08 PM	0.70	0.33	137	74	....	3.20	120	1.75	6.0
120[a]	" 9	4:25 AM	0.50	0.37	96	153	....	3.20	120	2.00	6.0
121[a]	" 9	10:00 AM	2.50	0.42	480	136	....	3.20	120	{2.00 / 0.50}	6.0
122[a]	" 9	1:05 PM	0.67	...	135	....	....	3.35	125	2.51	6.0
123	" 9	3:55 PM	6.83	0.55	1,306	93	7.1	3.18	119	2.51	6.0
124	" 9	11:18 PM	6.87	0.40	1,341	131	9.8	3.25	121	2.50	6.0
125	" 10	10:40 PM	4.83	0.42	948	87	9.2	3.27	122	2.50	6.0
126	" 11	3:55 AM	8.25	0.42	1,591	120	7.5	3.22	121	{2.00 / 0.25}	6.0
127	" 11	12:35 PM	8.42	0.33	1,603	109	6.8	3.18	119	{2.00 / 0.50}	6.0
128	" 12	3:35 AM	7.66	0.43	1,483	131	8.8	3.22	120	{1.50 / 0.50}	6.0
129	" 12	11:41 AM	10.19	0.58	1,984	87	4.4	3.25	121	1.50	6.0
130	" 12	10:35 PM	7.42	0.42	1,445	98	6.8	3.25	121	1.56	6.0
131	" 13	6:25 AM	11.92	0.63	2,346	93	4.0	3.28	122	2.00	6.0
132	" 13	6:58 PM	7.07	0.30	1,379	98	7.1	3.25	121	2.00	6.0
133	" 14	2:20 AM	10.67	0.50	2,104	175	8.7	3.28	122	2.00	6.0

and of the Efficiency of the American System—(Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
15	....	1	3,800	130	4	25	99.4	107	
25	....	1	5,400	400	10	50	99.1	108	
20	....	1	3,000	325	12	40	98.7	109	
18	2	1	3,000	190	5	75	97.5	110	
17	...	1	3,700	275	7	46	98.8	111	
18	....	1	4,000	150	17	95	97.6	112	
18	....	1	4,200	160	44	50	98.8	113	
21	20	1	3,200	85	55	70	97.8	114	Changed sand layer December 5.
15	12	1	3,200	6,700	475	1,800	43.8	115	
14	12	1	2,400	750	300	550	77.0	116	Agitated Dec. 7, 4:17 PM.
14	14	1	3,900	5,000	190	550	85.9	117	Agitated Dec. 8, 2:08 AM and 4:07 AM.
80	32	1	43,000	6,500	325	2,900	93.3	118	Agitated Dec. 8, 12:40 PM and 2:00 PM.
158	100	3	89,000	21,900	2,700	13,100	85.3	119*	
158	130	5	36,000	19,800	8,100	15,100	58.0	120*	
154	100	1	35,000	12,100	550	5,300	84.9	121*	
150	....	3	34,500	5,300	4,000	4,500	87.0	122*	Changed sand layer December 9, 2:00 PM.
150	40	3	26,700	7,100	3,200	4,400	83.5	123	
150	76	3	41,000	8,400	2,300	4,700	88.5	124	
80	30	1	25,300	1,800	850	1,400	94.5	125	
76	35	1	27,000	1,200	55	400	98.5	126	
33	....	1	26,500	1,600	70	450	98.3	127	
72	35	1	24,300	1,500	200	500	97.9	128	
70	55	1	23,000	1,400	475	800	96.5	129	
103	28	1	30,000	750	170	400	98.7	130	
89	28	1	22,000	425	60	240	98.9	131	
88	52	1	21,000	800	250	550	97.6	132	
80	30	1	15,000	800	95	300	98.0	133	Changed sand layer December 14, 1:00 PM.

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Alumina in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1896.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
134	Dec. 14	4:35 PM	7.42	0.45	1,413	65	4 6	3.18	119	2 00	6.0
135	" 15	12:27 AM	8.55	0.78	1,651	123	7.5	3.22	120	1.89	6.0
136	" 15	9:47 AM	6.35	0.42	1,195	85	7.1	3.14	117	1.75	6 0
137	" 15	7:06 PM	5.00	0.43	937	131	14.0	3.12	117	{1.50 0.51	6.0
138	" 16	12:32 AM	6.47	0.42	1,238	131	10.6	3.18	119	{1.50 0.51	6.0
139	" 16	7:25 AM	7.58	0.54	1,449	109	7 5	3.17	118	1.50	6.0
140	" 16	3:34 PM	6.43	0.50	1,240	93	7.5	3.22	120	1.50	6 0
141	" 16	10:30 PM	7.00	0.50	1,347	131	9.7	3.21	120	1.50	6.0
142	" 17	6:00 AM	8.00	0.40	1,540	103	6.7	3.21	120	1.51	6.0
143	" 17	9:05 PM	7.42	0.50	1,425	109	7.6	3.21	120	1 25	6.0
144	" 18	5:00 AM	8.00	0.58	1,533	103	6.7	3.20	120	1.25	6.0
145	" 18	6:05 PM	7.92	0.50	1,523	131	8.6	3.21	120	1.00	6.0
146	" 19	2:30 AM	9 50	0.72	1,824	98	5.4	3.20	120	1.01	6 0
147	" 19	12:43 PM	5.28	0.50	992	120	12.1	3.13	117	1.00	6.0
148	" 19	11:05 PM	5.92	0.50	1,138	125	11.0	3.20	120	0.75	6.0
149	" 20	5:30 AM	9.50	0.57	1,825	71	3.9	3.20	120	0.75	6.0
150	" 20	3:34 PM	6.47	0.58	1,239	115	9.3	3.20	120	0.75	6 0
151	" 20	10:35 PM	7.42	0.50	1,422	131	9.2	3.20	120	0.75	6.0
152	" 21	6:30 AM	9.63	0.53	1,860	115	6.2	3.22	120	0.75	6 0
153	" 21	4:40 PM	8.33	0.50	1,604	131	8.2	3.21	120	1.19	6.0
154	" 22	1:30 AM	10.72	0.25	2,044	. . .	....	3.18	119	2.51	6.0
155	" 22	3:40 PM	13.33	0.50	2,578	147	5.7	3.22	120	2.51	6 0
156	" 23	5:30 AM	11.17	0.50	2,154	163	7.6	3.22	120	2.51	6 0
157*	" 24	9:33 AM	2.28	0.72	423	131	....	3.10	116	2.51	6.0
158*	" 24	7:10 PM	7.83	0.50	1,306	163	10.7	3 21	120	{3.00 0.75	6.0
159	" 25	4:30 AM	6 58	1.00	1,236	98	7.9	3.13	117	{2 77 0.75	6.0
160	" 25	12:03 PM	6.95	0.58	1,328	87	6.5	3.18	119	{2.57 0.75	6.0

and of the Efficiency of the American System—(Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
75	29	1	14,900	600	300	350	97.6	134	
60	28	1	20,200	550	300	475	97.6	135	
56	25	1	14,700	475	210	275	98.1	136	
56	32	1	12,400	1,600	130	375	97.0	137	
54	21	1	17,700	800	140	240	98.6	138	
50	26	1	15,600	1,100	230	375	97.6	139	
50	25	1	18,000	550	210	275	98.5	140	
46	21	1	19,600	1,400	160	400	98.0	141	
37	19	1	17,000	1,100	220	350	97.9	142	
28	20	1	14,400	1,300	200	400	97.2	143	
27	15	1	14,300	1,200	230	350	97.5	144	
25	20	1	10,700	850	230	300	97.2	145	
26	20	1	13,000	600	200	300	97.7	146	
26	22	1	10,500	1,000	170	425	96.0	147	
22	23	1	11,500	600	250	375	96.7	148	
19	21	1	19,800	475	130	300	98.5	149	
18	20	1	16,600	800	220	425	97.4	150	
18	17	1	10,300	600	350	425	95.9	151	
18	16	1	6,200	600	200	450	92.7	152	
18	....	1	6,500	750	210	400	93.9	153	
170	38	1	55,900	13,500	750	3,600	93.6	154	
170	....	1	50,000	11,000	7,000	9,000	82.0	155	
162	60	1	15,000	12,100	5,100	7,900	83.4	156	Reduced thickness of sand layer to 15 inches Dec. 22, 1:00 PM.
150	48	2	71,000	3,400	2,600	2,900	95.9	157*	
165	....	1	96,000	3,700	180	850	99.1	158*	Increased thickness of sand layer to 20 inches Dec. 24, 11:50 AM.
165	53	1	37,500	2,700	325	900	97.6	159	
115	....	1	31,000	2,500	190	750	97.6	160	

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Alumina in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1898.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
161	Dec. 25	7:35 PM	11.42	0.50	2,209	131	5.9	3 22	120	3.00	6 0
162	" 26	7:30 AM	13.50	0.58	2,573	125	4.9	3.18	119	2.93	6.0
163	" 26	9:35 PM	12.42	0.50	2,370	87	3.7	3.17	118	2.75	6.0
164	" 27	10:53 AM	10.62	0.58	2,053	147	7.2	3.16	118	2.67	6.0
165	" 27	10:05 PM	11.92	0.83	2,287	115	5.0	3.20	120	2.51	6.0
166[a]	" 28	10:50 AM	1.08	0.66	215	90	....	3.31	124	2.50	6.0
167	" 29	5:30 AM	12.50	0.50	2,428	175	7.2	3.23	121	{2.25 / 0.75}	6.0
168	" 30	12:34 AM	6.48	0.70	1.210	104	8.6	3.11	116	2.25	2.5
169	" 30	7:45 AM	5.58	0.58	1,065	131	12.3	3.18	119	2.25	2.5
170	" 30	1:55 PM	3.08	0.58	748	131	17.5	4.04	151	2.25	2.0
171	" 30	5:35 PM	3.42	0.42	867	142	16.4	4.12	154	2.28	2.0
172	" 30	11:00 PM	30.50	0.82	2,256	125	5.5	1.23	46	2.40	7.0
	1899										
173	Jan. 1	6:19 AM	16.85	0.67	1,381	125	9.0	1.37	51	2.27	7.0
174	" 2	6:03 AM	3.75	0.42	721	147	20.4	3.20	120	2.25	6.0
175	" 2	7:05 PM	10.92	0.67	2,117	109	5.1	3.23	121	1.50	6.0
176	" 3	6:40 AM	6.33	0.50	1,527	141	9.2	4.02	150	1.53	5.0
177	" 3	1:30 PM	13.50	0.75	2,589	103	4.0	3.20	120	2 06	6.0
178	" 4	3:45 AM	10.25	0.60	1,976	128	6.5	3.21	120	2.50	6 0
179	" 4	2:34 PM	11.43	0.70	2,198	98	4.5	3.20	120	1.37	6 0
180	" 5	2:43 AM	5.87	0.42	1,145	125	10.9	3.25	121	1.37	6 0
181	" 5	2:50 PM	8.17	0.50	1,564	147	9.4	3.20	120	{2.25 / 0.50}	6.0
182	" 5	11:30 AM	14.75	0 42	2,844	125	4 4	3.21	120	2.50	6.0
183	" 6	8:20 PM	5.67	0.75	1,088	142	13.0	3 20	120	2.50	0 5
184	" 7	9:05 AM	5.58	0.50	1,062	136	12.8	3.17	119	{2.00 / 0.50}	6.0
185	" 7	3:10 PM	7.33	0.50	1,400	152	10.9	3.18	119	{2.55 / 0.50}	6.0
186	" 7	11:00 PM	11.00	0 50	2,112	141	6.7	3.20	120	2.75	6.0

and of the Efficiency of the American System – (Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
160	29	1	26,200	1,300	250	425	98.4	161	
134	29	1	24,000	600	100	250	99.0	162	
95	25	1	24,000	1,400	210	350	98.5	163	
83	24	1	22,500	425	130	180	99.2	164	
70	25	1	17,000	600	50	120	99.3	165	
75	....	1	15,300	400	70	210	98.6	166	
81	26	1	16,000	100	18	43	99.7	167	
81	54	1	27,600	200	25	55	99.8	168	
80	46	1	22,100	400	33	100	99.5	169	
78	46	1	22,000	500	60	140	99.4	170	
78	38	1	21,200	275	29	80	99.6	171	
76	38	1	13,500	450	7	49	99.6	172	
47	27	1	8,700	190	6	26	99.7	173	
51	21	1	7,900	550	34	90	98.9	174	
52	23	1	9,300	110	34	65	99.3	175	
50	34	1	16,400	400	200	275	98.3	176	
65	27	1	20,300	350	8	120	99.4	177	
58	15	1	18,800	400	26	65	99.7	178	
64	22	1	14,900	325	190	250	98.3	179	
59	....	1	19,900	850	140	480	97.6	180	
188	42	2	25,800	1,700	30	350	98.6	181	
198	30	1	29,800	550	80	230	99.2	182	
206	89	1	13,500	1,000	200	550	95.9	183	
118	72	1	24,900	2,000	300	950	96.2	184	
130	70	1	19,900	950	14	275	98.6	185	
130	60	1	29,500	750	130	375	98.7	186	

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Alumina in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1898.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
187	Jan. 8	10:30 AM	12.50	0.50	2,404	153	6.4	3.21	120	2.75	6.0
188	" 8	11:30 PM	11.50	0.58	2,207	131	5.9	3.20	120	2.75	6.0
189	" 9	11:35 AM	10.42	0.50	2,010	136	6.8	3.21	120	2.22	6.0
190	" 9	10:30 PM	11.55	0.52	2,210	133	6.0	3.19	120	1.50	6.0
191	" 10	10:31 AM	11.48	0.50	2,214	147	6.6	3.22	121	1.50	6.0
192	" 10	10:30 PM	11.55	0.58	2,204	125	5.7	3.18	119	2.50	6.0
193	" 11	10:35 AM	10.92	0.50	2,111	131	6.2	3.22	120	2.50	6.0
194	" 12	9:33 PM	6.53	0.55	1,255	153	12.2	3.20	120	2.25 / 0.50	6.0
195	" 13	4:38 AM	7.87	0.50	1,513	142	9.4	3.20	120	2.25 / 0.50	6.0
196	" 13	1:00 PM	11.17	0.52	2,154	120	5.6	3.21	120	2.25	6.0
197	" 14	12:50 AM	11.67	0.50	2,252	125	5.5	3.21	120	2.25	6.0
198	" 14	1:00 PM	11.25	0.58	2,156	125	5.6	3.20	120	2.25	6.0
199	" 15	12:50 AM	11.67	0.47	2,250	125	5.5	3.21	120	2.25	6.0
200	" 15	12:58 PM	11.20	0.58	2,139	131	6.1	3.18	119	2.25	6.0
201	" 16	12:45 AM	11.25	0.50	2,177	142	6.5	3.22	121	2.25	6.0
202	" 16	12:29 PM	11.72	0.55	2,241	136	6.1	3.19	120	2.00	6.0
203	" 17	12:45 AM	10.25	0.47	1,973	131	6.6	3.20	120	2.00	6.0
204	" 17	11:28 AM	7.53	0.60	1,420	120	8.4	3.15	118	2.00 / 0.75	6.0
205	" 17	7:36 PM	8.40	0.58	1,611	136	8.4	3.20	120	2.50	6.0
206	" 18	4:35 AM	9.92	0.50	1,910	131	6.9	3.21	120	2.51	6.0
207	" 18	3:00 PM	10.00	0.58	1,941	142	7.3	3.23	121	3.00 / 0.51	6.0
208	" 19	1:35 AM	9.92	0.50	1,914	142	7.4	3.21	120	3.00	6.0
209	" 19	12:00 M	2.83	0.50	575	120	....	3.39	127	3.00	6.0
210	" 19	3:28 PM	11.50	0.58	2,212	109	4.9	3.20	120	2.75	6.0
211‡	" 20	3:35 AM	10.42	0.50	2,003	120	6.0	3.20	120	2.75‡	6.0
212	" 20	2:29 PM	10.52	0.58	2,017	131	6.5	3.20	120	2.75	6.0

‡ Fed 0.75 grain additional at filter for first 30 minutes of run.

and of the Efficiency of the American System—(Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
118	38	1	23,200	700	100	250	98.9	187	
85	33	1	22,800	550	28	120	99.5	188	
56	34	1	16,600	325	60	130	99.2	189	
51	31	1	13,100	375	65	150	98.9	190	
94	31	1	15,400	350	80	150	99.0	191	
133	55	1	19,200	375	75	150	99.2	192	
128	68	1	16,700	550	28	120	99.3	193	
120	50	1	15,000	600	28	140	99.1	194	
142	46	1	13,600	425	8	49	99.6	195	
145	45	1	11,800	100	4	38	99.8	196	
123	42	1	9,600	110	14	38	99.6	197	
115	41	1	11,800	200	8	31	99.7	198	
96	40	1	16,100	100	11	32	99.8	199	
90	42	1	13,700	75	23	48	99.6	200	
90	38	1	13,000	210	11	33	99.7	201	
90	46	1	14,000	75	20	32	99.8	202	
150	48	1	19,700	170	15	43	99.8	203	
155	80	1	26,500	190	75	120	99.5	204	
165	76	1	23,000	550	200	425	98.2	205	
185	63	1	19,100	1,100	120	550	97.1	206	
153	80	1	19,800	450	180	250	98.7	207	
158	83	1	17,700	900	190	550	96.9	208	
150	65	2	14,700	650	500	550	96.5	209*	
150	65	1	14,500	275	80	200	98.6	210	
150	54	1	18,600	475	37	110	99.4	211‡	
124	52	1	19,500	250	21	70	99.6	212	

‡ Fed 0.75 grain additional at filter for first 30 minutes of run.

TABLE No. 1 — *Summary of the Quantitative Results*

Number of Run.	Began.		Periods of Time. Hours.		Quantities of Water. Cubic Feet.		Percentage which Wash Water is of Filtered Water.	Average Rate of Filtration.		Average Amount of Applied Sulphate of Alumina in Grains per Gallon of Filtered Water.	Period of Coagulation. Hours.
	Date—1896.	Hour.	Service.	Wash.	Filtered.	Wash.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.		
213	Jan. 21	1:35 AM	11.42	0.50	2,195	131	6.0	3.20	120	2.75	6.0
214	" 21	1:28 PM	13.53	0.67	2,580	153	5.9	3.18	119	2.75	6.0
215	" 22	3:39 AM	12.10	0.55	2,281	120	5.3	3.14	117	2.75	6.0
216	" 22	4:17 PM	6.72	0.58	1,286	131	10.2	3.19	119	2.75	6.0
217	" 23	3:35 AM	9.92	0.48	1,909	120	6.3	3.20	120	2.75	6.0
218	" 23	1:58 PM	10.10	0.53	1,931	125	6 5	3.20	120	2.75	6.0
219	" 24	12:37 AM	9.80	0.47	1,885	131	7.0	3.21	120	2.75	6.0
220†	" 24	10:53 AM	6.12	0.83	1,220	76	6.2	3.32	124	2.75	6.0
221	" 24	5:50 PM	7.42	0.53	1,427	125	8.8	3.20	120	2.00	6.0
222	" 25	1:47 AM	11.22	0 58	2,160	147	6.8	3.24	121	2.00	6.0

† Changed rate of filtration every 15 minutes, using rates 153, 120, and 90 million gallons per acre respectively in rotation.

and of the Efficiency of the American System—(Continued).

Estimated Average Amount of Suspended Matters in Plain Subsided Water—Parts per Million.	Estimated Average Amount of Suspended Matters in Water Applied to Filter—Parts per Million.	Average Degree of Clearness.	Bacteria per Cubic Centimeter.				Average Bacterial Efficiency.	Number of Run.	Remarks.
			Subsided Water.	Effluent.					
				Maximum.	Minimum.	Average.			
136	57	1	18,500	325	65	125	99.3	213	
130	56	1	20,800	325	20	110	99.5	214	
130	50	1	12,400	180	22	85	99.3	215	
130	70	1	13,500	1,000	33	190	98.6	216	
124	53	1	11,900	240	26	180	98.4	217	
110	50	1	19,400	275	20	48	99.8	218	
78	50	1	14,100	120	26	80	99.4	219	
70	35	1	8,400	90	7	22	99.7	220†	
65	36	1	8,500	230	25	49	99.4	221	
68	38	1	6,000	240	8	46	99.2	222	

†Changed rate of filtration every 15 minutes, using rates 153, 120, and 90 million gallons per acre respectively in rotation.

TABLE No. 2.

Average Results of Chemical and Bacterial Analyses of the Effluent of the American System, arranged by Months.

[Chemical Results expressed in Parts per Million.]

	1898.				1899.
	Sept.	Oct.	Nov.	Dec.	Jan.
Oxygen consumed	1.5	1.1	1.4	1.1	0.9
Nitrogen as albuminoid ammonia	.081	.070	.079	.069	.052
Nitrogen as free ammonia	.033	.026	.022	.....	.023
Nitrogen as nitrites	.002	.001	.000	.001	.001
Nitrogen as nitrates	.43	.48	.82	.93	1.09
Total residue on evaporation	161.	164.	121.	135.	107.
Alkalinity*	47.	51.	30.	38.	20.
Sulphuric acid	24.	30.	29.	34.	33.
Dissolved oxygen	6.0	5.3	7.9	11.2	10.2
Bacteria per cubic centimeter	1400.	45.	180.	1200.	170.

*In no case was the effluent acid due to undecomposed sulphate of alumina, the lowest alkalinity found being 13 parts, on run No. 195.

CHAPTER IX.

Discussion of the Leading Factors associated with the Efficiency and Cost of Operation of the American System of Purification, receiving Plain Subsided Water, based on the Results of these Experiments.

The subject matter of this chapter corresponds to the presentation at some length in Chapter V with reference to English filters. For convenience the discussion upon the American system is taken up with respect to three separate points, as follows:

I. The quality of the effluent with especial reference to the bacterial efficiency of the filter.

II. The cost of construction and of operation of the filter.

III. Resumé with an outline of conditions favoring the most efficient and at the same time the most economical filtration by this method.

In the discussion of the first two of the three sections outlined above, the data for which are summarized in Chapter VIII, the principal factors for consideration are practically the same, and are as follows:

1. The composition of the applied water.
2. The application of chemical.
3. The quantity of applied chemical.
4. The provisions for coagulation and supplementary subsidence.
5. The degree of coagulation of the chemically treated water as it enters the sand layer of the filter.

6. The construction of the sand layer with reference to size of sand grains, thickness of layer, and composition of sand.

7. The rate of filtration.

8. The regulation and control of the rate of filtration.

9. The head employed in the operation of the filters.

10. The washing of the sand layer to remove clogging.

11. The agitation of the surface of the sand layer as a partial substitute for washing.

12. The relation of proper attention and supervision to the operation of the filters.

I.—ON THE PRACTICAL SIGNIFICANCE OF LEADING FACTORS AFFECTING THE QUALITY OF THE EFFLUENT OF THE AMERICAN SYSTEM, WITH ESPECIAL REFERENCE TO THE BACTERIAL EFFICIENCY.

It will be noted that "the appearance of the effluent" and "the removal of organic matter," subjects which were discussed at length in Chapter V with reference to English filters, are not considered in separate sections in this chapter. The reasons of this are set forth below:

The Comparative Unimportance, from a Practical Standpoint, of the Consideration of the Appearance of the Effluent and the Removal of Organic Matter in the American System.

Without exception it was found that, under the conditions of operation at this plant, the effluent was brilliant in appearance, and the removal of organic matter was satisfactory, at all times when the bacterial efficiency was satisfactory. As the bacterial efficiency is the point of greatest importance, it may be stated positively that when the American system was operated here so as to give satisfactory bacterial results, no attention was required for the questions of appearance of effluent and removal

of organic matter, because in the latter respects the results were practically perfect. So far as could be learned, nitrification was not an appreciable factor in the removal of organic matter.

Comparing the behavior of English and American filters in this respect, it is seen that there is a complete reversal in the relation of the results obtained. That is to say, while English filters gave good bacterial results and a poor appearance of the effluent and indifferent or poor removal of organic matter, the American system could give just the opposite.

The explanation of this sharply defined reversal in the relation of the results obtained from English and American filters, under the existing local conditions, is not perfectly clear. It appears, however, to be associated largely with differences in the action of the coagulating chemical upon the bacteria, the minute particles of clay and of organic matter in the applied water, and with their relative sizes before coagulation.

In the case of English filters, it appears to be the difference in sizes which causes largely the practically complete removal of bacteria, with very imperfect removal at times of the much smaller particles of clay and suspended organic matter. When a coagulating chemical is added to such a water before its application to an American filter, it seems that the chemical has a greater power to coagulate and to aggregate the clay and organic matter into relatively larger masses than is the case with the bacteria. Furthermore, the adhesiveness of the gelatinous aluminum hydrate to the rough surface of the clay particles appears to be distinctly more than to the comparatively smooth membranous walls of the bacteria. Combining these two factors, they appear to go a long way towards explaining the stated differences in the behavior of the two types of filters, as judged from present information.

The appearance of the effluent and the removal of organic matter receive no further especial attention in this chapter.

The Composition of the Applied Water.

The influence of the composition of the applied water was shown both directly and indirectly. For the sake of explicitness these two lines are referred to separately.

Direct Influence.—When the number of bacteria in the applied water became very high, over about 50,000 per cubic centimeter, there appeared to be a tendency for the bacterial efficiency to diminish somewhat, other conditions being equal. Practically speaking, this factor was not found to be one of great importance.

The analytical results show that *bacillus coli communis*, the principal intestinal germ, was present in the applied water quite regularly, and that it passed through filter No. 20, but in greatly diminished numbers. As a rule, the effluent of the American filter (No. 20) was tested for the presence of this germ once a week, 50 cubic centimeters of water being employed for each test. The results showed that in seven of the fifteen tests made the germ was present.

The practical significance of these tests is that the American system, like all others now known, is not germ-proof; that sewage or disease germs, if present in the applied water, will be reduced probably to no greater degree than ordinary water bacteria, and that the number of dangerous germs in the effluent will be roughly proportional to those in the applied water, although in very largely reduced numbers, of course.

In this connection it is to be stated that the water coming from the Front Street intake and applied to this filter contained correspondingly more sewage bacteria than will be the case with river water taken from the new intake at California.

Obviously any improvement in the specific bacterial composition of the applied water will result in a safer character of filtered water.

By far the most important feature in the composition of the applied water was that it possessed sufficient alkaline compounds (lime and magnesia) so that, with efficient management, there would be no grounds to expect the inadmissible presence of undecomposed chemical in the filtered water.

Indirect Influence.—Indirectly, the marked variations in the amount and character of the suspended matter influenced the character of the effluent through the adjustment of the applied chemical to meet properly the varying demand upon it. This latter point is one of vital importance, as is outlined below.

When the amount of suspended matter in the applied water is comparatively large, it causes the filter to be washed at more frequent intervals. The result of this is a tendency towards a slight deterioration in the quality of the effluent, although in a battery of filters this effect would be almost completely disguised, practically speaking.

The Application of the Chemical.

It is imperative that the chemical shall be applied according to the prescribed rate (adjusted to the composition of the applied water). If the application of chemical should stop for a short time or depart from the prescribed rate, more or less disastrous results are bound to follow.

The Quantity of Applied Chemical.

When the quantity of applied chemical is properly adjusted to the varying composition of the applied water (Ohio River water subsided for about three days), it can be positively stated that the quality of the effluent of the American system, under

suitable conditions of construction and operation, will be perfectly satisfactory, as judged practically in the light of our present knowledge of water purification.

The actual bacterial efficiency accomplished by filter No. 20 alone and in connection with plain subsidence is shown in the summaries below. The first one includes all bacterial results after the first week of operation, and the second covers the same period, but excludes the results from December 6 to 10 and 22 to 24, both inclusive, when changes were made in the sand layer, and the new sand was put in place in a more or less frozen condition.

Summaries of Bacterial Results—American System.

Period.	Bacteria per Cubic Centimeter.			Bacterial Efficiencies.	
	River Water.	Subsided Water.	Effluent of Filter No. 20.	Filtration alone.	Filtration and Subsidence
Sept. 21, 1898, to Jan. 25, 1899	27,200	12,600	400	96.8	98.5
Ditto, but excluding Dec. 6 to 10 and Dec. 22 to 24, 1898.....	25,000	10,900	160	98.5	99.4

It is hardly necessary to state that the bacterial efficiency of filtration proper is computed by dividing the difference in the numbers of bacteria in the subsided water and in the effluent by the former number; and of filtration and subsidence in a corresponding manner from the numbers of bacteria in the river water and in the effluent.

Relative to the removal of bacteria, it is believed that the quantity of applied chemical employed in the operation of filter No. 20 was rather too low when viewed strictly from a hygienic standpoint, especially during the earlier part of the operations. As nearly as can be estimated, this filter was operated on a basis

of an annual average application of about 1.25 grains of chemical per gallon of applied water. This quantity would enable the system to yield a brilliant effluent and give a good removal of bacteria—about 99 to 99.5 per cent for an annual average removal of the river water bacteria.

But if about one third of a grain of chemical per gallon in addition were applied on an average, the evidence indicates that the bacterial results would be as good as is practicable to obtain by any method now known. That is to say, the bacteria in the effluent would average less than 100 per cubic centimeter, and the annual average removal of the river water bacteria from present evidence would amount to fully 99.5 per cent.

On the last stated basis the annual average quantity of applied chemical is estimated at 1.6 grains per gallon of filtered water. With this annual average amount of applied chemical the quantities for different grades of subsided water, based on the present data, would be on an average substantially as given below, although during freshets the optimum quantity is liable to deviate by 0.25 grain from the following:

Estimated Average Amounts of Required Chemical for Different Grades of Subsided Water in the American System.

SUSPENDED MATTER.		CHEMICAL REQUIRED.
Parts per million,	10	0.75 grains per gallon.
" "	25	1.25 " "
" "	50	1.50 " "
" "	75	1.95 " "
" "	100	2.20 " "
" "	125	2.45 " "
" "	150	2.65 " "
" "	175	2.85 " "
" "	200	3.00 " "
" "	300	3.80 " "
" "	400	4.40 " "

The actual quantities day by day would be quite variable, as shown in the following table, prepared from curves indi-

cating the required amount of chemical in accordance with the data of the last table, and from the daily amounts of suspended matter in the subsided water, on the basis of 75 per cent removal of matters suspended in the river water due to subsidence for three days (see page 124).

Table showing the Estimated Quantity of Applied Chemical (Sulphate of Alumina) in Grains per Gallon of Filtered Water required for each Day of 1898, when the Applied Water received Preliminary Plain Subsidence for Three Days.

Day.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1.....	1·6	1·5	1·5	1·3	2·1	1·6	1·6	2·2	1·3	0·8	2·0	1·2
2.....	1·8	1·8	0·8	1·3	1·7	1·6	1·3	2·0	1·1	0·8	1·6	1·3
3.....	2·4	2·1	1·2	1·5	1·3	1·7	1·2	2·0	1·1	0·7	1·5	0·8
4.....	2·2	1·6	1·3	1·5	1·3	1·3	1·1	2·0	1·1	0·8	1·3	1·2
5.....	1·9	1·4	1·3	1·5	1·4	1·4	1·2	2·0	1·0	0·8	1·3	2·4
6.....	1·6	1·3	1·2	2·0	1·5	1·5	1·4	2·2	0·9	0·8	1·3	2·3
7.....	2·8	1·3	1·1	1·9	2·2	1·0	1·5	3·1	0·8	0·8	1·3	1·9
8.....	3·0	1·2	0·9	1·5	2·0	1·0	1·1	3·3	0·8	0·7	1·3	1·7
9.....	3·7	1·2	1·2	2·2	2·0	0·9	1·2	3·8	0·8	0·7	1·9	1·8
10.....	5·4	1·5	1·7	1·5	2·0	0·9	1·1	3·0	0·7	0·9	2·4	1·8
11.....	3·6	1·8	2·0	1·6	1·7	0·8	1·0	3·3	1·2	0·9	2·3	1·6
12.....	3·4	2·2	2·2	1·5	1·8	1·8	1·0	3·9	0·8	0·9	1·9	1·4
13.....	2·9	2·1	2·0	1·6	1·7	1·0	1·0	2·7	0·9	0·9	2·4	1·5
14.....	2·6	1·6	1·7	1·3	1·3	1·0	0·9	2·2	0·7	0·9	2·6	1·1
15.....	2·4	2·3	1·2	1·2	1·5	1·1	1·1	1·6	0·8	0·7	2·4	0·8
16.....	2·3	1·8	1·5	1·3	1·5	0·7	1·1	2·1	1·4	0·7	2·2	0·7
17.....	2·2	1·8	2·2	1·0	1·4	0·7	1·1	2·5	0·8	1·8	1·9	0·7
18.....	2·0	1·7	2·8	1·2	1·2	0·8	1·1	2·8	0·7	0·8	1·8	0·7
19.....	2·0	1·6	1·9	1·5	1·5	0·7	1·8	2·4	1·2	0·8	1·6	0·8
20.....	2·0	2·2	2·4	1·8	2·2	1·0	2·1	2·5	1·5	0·8	1·7	3·6
21.....	2·1	1·9	3·0	1·0	2·2	1·2	2·0	2·2	1·8	0·8	1·6	1·9
22.....	1·9	1·5	2·4	1·0	2·0	1·3	1·9	1·9	1·8	0·8	1·5	2·2
23.....	2·2	2·0	2·4	1·0	2·0	1·5	1·6	1·8	1·3	0·9	1·5	2·1
24.....	2·5	1·7	2·5	1·4	1·7	1·6	1·3	2·5	1·3	1·4	1·5	2·0
25.....	2·5	2·0	2·3	1·8	1·3	1·5	1·5	2·8	1·2	2·4	1·4	2·1
26.....	2·6	1·5	2·0	1·0	2·0	1·5	2·2	9·6	1·1	2·6	1·2	2·1
27.....	2·6	1·3	2·0	1·0	1·6	1·5	2·7	2·3	1·3	2·2	1·3	2·1
28.....	1·9	1·4	2·0	1·7	1·5	1·5	3·2	2·1	1·1	2·1	1·3	1·8
29.....	1·9	.....	2·0	1·9	1·6	1·7	1·9	1·8	1·0	1·9	1·3	1·5
30.....	1·7	.....	1·8	2·3	1·5	1·8	2·1	1·6	0·9	1·7	1·2	1·3
31.....	0·9	.....	1·4	.....	1·6	.....	2·3	1·4	.....	1·9	.....	1·9

In the operation of this experimental plant much assistance was derived from the rapid estimations of the amount of suspended matter present in the subsided water by means of the diaphanometer (see pages 99 and 287). From the amount of suspended matter thus obtained it was an easy matter to note from curves and tables what the approximate amount of applied chemical should be.

Relative to the variations in the amount of applied chemical, it is to be stated that in practice they would not be so great, because in the subsiding reservoirs several days' supply of river water would be mixed together more or less, and the suspended matters in the subsided water would be more uniform. However, the variability in the amount of applied chemical would be great enough at best, and shows the imperativeness of skillful supervision.

Margin of Alkalinity in Water after decomposing the Chemical.—It is imperative that the water at all times should contain a sufficient quantity of alkaline compounds (alkalinity) to decompose the applied chemical, and have some margin of alkalinity remaining as a factor of safety. Accordingly, one of the most important points in studying the applicability of this system of purification for any water is to determine whether or not the applied chemical would be decomposed by the natural constituents of the water, and whether the application of alkali to the water would be needed.

As stated on page 19, the available evidence shows that the minimum alkalinity in this river water is 20 parts per million. Further, the indications are that this minimum quantity may occur on three or four occasions during a year (at times of floods), and continue for two to three days for a maximum period.

On pages 287 and 278 it was shown that some of the applied

chemical is absorbed by the suspended matters in the water, and that 20 parts per million of alkalinity is capable of decomposing 3.0 grains per gallon of sulphate of alumina of ordinary composition.

Turning back to the last table, it is found that on 354 days of the year 1898 the amount of required chemical (with three days' plain subsidence) would not have exceeded the quantity capable of being decomposed by the minimum alkalinity in the river water. On the 11 remaining days the estimated amount of required chemical, with the evidence upon the required amount of alkalinity and the alkalinity actually present, is shown in the following table, in connection with which it is to be recalled that the alkalinity of the water was not determined prior to the operation of the plant (March 28).

Date—1898.	Required Chemical—Grains per Gallon.	Alkalinity in Parts per Million.		Margin of Remaining Alkalinity.
		Required for Decomposition.	Present in Water.	
January 9.....	3.7	25	?	Probably ample.
January 10....	5.4	36	?	Prob. exhausted.
January 11.....	3.6	24	?	" "
January 12.....	3.4	23	?	Probably ample.
July 28.....	3.2	22	60	Ample.
August 7.....	3.1	21	44	"
August 8.....	3.3	22	40	"
August 9.....	3.8	26	37	"
August 11.....	3.3	22	34	"
August 12.....	3.9	26	20	Exhausted.
December 20...	3.6	24	60	Ample.

The evidence shows that on only 3 of the 365 days in 1898 would it have been impossible to have added the required amount of sulphate of alumina without danger of the undecomposed chemical passing into the filtered water. This is

not a serious matter under good management, because the difficulty could be readily obviated by stopping the river water on those days, and taking advantage of the storage capacity of the subsiding basins to maintain the city's supply.

After a purification plant, constructed on the lines under consideration, had been in operation for some years, the period of plain subsidence would decrease to two days, due to the increased consumption of water and its more rapid passage through the system. Under these circumstances the average percentage of removal of suspended matters by subsidence would be 70 instead of 75 (see pages 124 to 127). On this basis there would be more chemical required, notably during freshets in the river. The evidence shows that under these conditions there would have been fifteen days in 1898 when the required chemical would have exceeded three grains per gallon, the amount capable of decomposition by the minimum quantity of alkalinity in the river water. The evidence for these fifteen days, corresponding to that in the last table, is as follows:

Date—1898.	Required Chemical—Grains per Gallon.	Alkalinity in Parts per Million.		Margin of Remaining Alkalinity.
		Required for Decomposition.	Present in Water.	
January 8.....	3.3	22	?	Probably ample.
January 9.....	4.2	28	?	Prob. exhausted.
January 10.....	6.5	43	?	" "
January 11.....	4.1	28	?	Probably ample.
January 12.....	3.9	26	?	" "
January 13.....	3.1	21	?	" "
March 21.....	3.2	22	?	" "
July 28.....	3.6	24	60	Ample.
August 7.....	3.5	24	44	"
August 8.....	3.8	26	40	"
August 9.....	4.3	29	37	"
August 10....	3.3	22	37	"
August 11.....	3.8	26	34	"
August 12.....	4.4	30	20	Exhausted.
December 20...	4.0	27	60	Ample.

As in the case with three days' subsidence, it would only have been necessary to have stopped the river pumps on three days during 1898, with a period of two days for plain subsidence. In all probability the condition in practice would have been somewhat less difficult than is indicated by the data in the last two tables, owing to the removal of suspended matters by subsidence during the periods of freshets being greater ordinarily than the average removal, and to a mixing together of the water in the reservoirs, thus eliminating in a measure the the excessive turbidity and the minimum alkalinity of the water.

Relative to the question of applying alkali to this river water under these conditions of purification, the evidence is decisive that it would be unnecessary.

Influence upon Quality of Effluent.—Independent of the question of bacterial efficiency, which would be satisfactory as stated at the beginning of this topic (page 339), the relation between the quantity of applied chemical and the quality of the effluent may be reviewed briefly, as follows:

1. So far as relates to the human system, the required quantities of chemical would mean simply a conversion of some of the carbonate of lime and magnesia into the form of the sulphate of these bases. There is no reason to believe that this would have any influence at all, practically speaking, as the quantities present in the effluent were too small, and less than that naturally present in many good public water supplies, including some on the Ohio River.

2. For household purposes the quality of the effluent would be perfectly satisfactory, and would require no more soap than the river water when used cold or warm (unboiled). If the filtered water were thoroughly boiled, it would be somewhat harder than boiled river water, the increase in permanent hardness ranging from 5 to 30 and averaging about 12 parts

per million. In grains per gallon these figures become 0.3, 1.75, and 0.7, respectively.

3. Concerning its solvent action on metals, this filtered water could be safely used in lead pipes, because the calcium bicarbonate would form a thorough protective coating. The effluent would have nominally a slightly greater corroding action on uncoated iron in the presence of oxygen than would the river water, due to the liberated carbonic acid. The quantities would be very small, 44 per cent of those stated for permanent hardness in the last paragraph. Practically speaking, this is of no significance, as the filtered water would contain less than half as much carbonic acid as is present further down the river.

4. When used in boilers the calcium sulphate (in quantities stated above under permanent hardness) added to the water is undesirable, but the amounts are too small to be seriously objectionable. In fact, it is quite likely that the removal of suspended matter from the river water might fully compensate, if not more than do so, for the conversion of lime from the carbonate into the sulphate.

The Provisions for Coagulation and Supplementary Subsidence of the Plain Subsided Water after Chemical Treatment.

The principal effect of the period of coagulation and subsidence after chemical treatment was on the quantitative efficiency, but the period also had an indirect effect on the average character of the effluent of a purification system in that, with turbid waters, a short period caused the filter to be washed more frequently. Immediately after washing the quality of the effluent was at times somewhat deteriorated, and the improvement of this somewhat unsatisfactory effluent by dilution with the effluent from other filters was less complete as the period between washings is shortened.

Directly, the quality of the effluent seemed to be affected only to a very slight degree, if at all, by the period of coagulation within the limits studied (0.1 to 6.0 hours) when the amount of suspended matter in the water to be treated was less than 25 parts per million. Under these conditions the bacterial efficiency was normally about the same with the long as with the short periods, and the only comparison is in the actual numbers of bacteria present in the effluent, normally very low in both cases.

This is illustrated by the following representative averages of actual runs on this class of water.

Number of Runs Averaged.	Period of Coagulation. Hours.	Grains of Chemical per Gallon.	Suspended Matters—Parts per Million.	Average Bacteria per Cubic Cen. in Effluent.	Average Bacterial Efficiency.
28, 31, 36	0.5	0.80	15	18	98.5
27, 32, 37	6.0	0.80	13	37	98.5

At times the increase in efficiency with the short period was very well marked. The conditions favoring this departure from the normal seemed to be associated with the character of the suspended matters, as coarse material reduced by subsidence the aluminum hydrate in the water passing upon the filter in the case of the long period, and increased the coagulating effect with the short period. This is well illustrated by the results of two runs (Nos. 104 and 105) made during the latter part of November, and which are recorded in the next table.

With regard to the effect of direct application of the chemical to the water within the filter tank (or in the inlet pipe), so far as it relates to the quality of the effluent, there did not seem to be any appreciable difference between the effect then and with 0.5 hour's subsidence with this type of water. This is

shown by the average results on runs Nos. 109 to 112, which are given in the next table:

Number of Runs.	Period of Coagulation. Hours.	Grains of Chemical per Gallon.	Suspended Matters—Parts per Million.	Average Bacteria per Cubic Cen. in Effluent.	Average Bacterial Efficiency.
104	0.5	1.27	21	130	96.9
105	6.0	1.26	25	300	91.4
111, 112	0.1	1.50	18	70	98.2
109, 110	0.5	1.50	19	58	98.1

Concerning the direct effect of the period of coagulation and subsidence with more turbid waters, there was a decided gain in favor of the long period over the short one. This is clearly shown by the following representative runs, which are for convenience presented in the form of pairs of runs under practically parallel conditions, and with averages of the corresponding runs of each pair:

Number of Runs.	Period of Coagulation.	Grains of Chemical per Gallon.	Suspended Matters—Parts per Million.	Average Bacteria per Cubic Cen. in Effluent.	Average Bacterial Efficiency.
38	0.5	0.72	55	100	98.0
42	6.0	0.70	48	65	97.7
40	0.5	1.01	54	50	98.5
43	6.0	1.00	45	20	99.2
45	0.5	2.00	114	180	96.6
44	6.0	2.00	120	43	99.3
51	0.5	1.25	78	190	93.0
52	6.0	1.25	77	90	96.4
48	0.5	1.25	72	190	94.9
50	6 0	1.25	77	90	96.4
56	0.5	1.51	39	80	95 3
55	6.0	1.52	42	20	99.4
72	0.5	1.50	47	300	99.1
71	6.0	1.52	47	70	99.1
Average....	0.5	1.32	66	156	96.1
	6.0	1.32	65	57	98.2

In this connection it is well to note, however, that the economic operation of the system of purification would demand the use of the long period (six hours) only under the conditions of very turbid water.

In fact, with certain grades of fairly clear water, as shown already on page 349, in the case of runs Nos. 104 and 105, the long period (six hours) would not give as good qualitative results as would a period of 0.5 hour. From a qualitative standpoint the question of a second application of chemical to the water approximately at the entrance to the filters is a factor of much practical importance, especially with reference to the operation and control of the system. If for any reason the primary application of chemical to a very turbid water at the entrance to the coagulating basin, made on the basis of required amounts, as shown on page 341, should be too small, this could be satisfactorily corrected by a second application shortly before the water enters the filters. The question of making a secondary application of chemical uniformly at times of very turbid water does not appear to be necessary or advisable; but before a final conclusion is reached further evidence is required upon the point. Concerning the intermediate point of application in these devices (2.5 hours), its presence was a convenience in securing good qualitative results, although it is doubtful whether the advantages from its use in practice would compensate for the expense which it would involve.

Degree of Coagulation of the Applied Water as it enters the Sand Layer.

Experience shows that, in the filtration of the unsubsided Ohio River water by this type of filter, the effluent is ordinarily of a satisfactory quality when the applied water as it

enters the sand layer is coagulated into flakes or masses of a size which is readily discernible to the eye.

In the operation of this plant, where the comparatively large particles in the river water were removed by subsidence, it was found that it was practically impossible to secure this visibly coagulated appearance of the subsided water, even when the applied chemical was largely in excess of that required for a satisfactory removal of the bacteria.

Indirectly this affected somewhat the quality of the effluent at times, because it removed a ready guide as to the approximate amount of required chemical. Naturally it makes a plant of this system more difficult to operate, and requires the use of a well-formulated basis or system of operation, with reference to the quantity of applied chemical, an outline of which was given on page 341.

The Construction of the Sand Layer.

It is considered that one of the most important points learned by these investigations consisted in the demonstration of the superiority under the local conditions of the use of finer sand than hitherto employed in filters of this type. By virtue of the greater frictional resistance and retentive capacity of the fine sand, it was possible "to run the filter dry," practically speaking. That is, to operate the filter until the full head was used up. In this way the frequent "breaks" or marked deterioration in the quality of the effluent, when the total head was only partially utilized, were avoided.

In the practical operation of a plant, especially during freshets in the river, the advantage of this elimination of "breaks" and the resulting unsatisfactory effluent would be considerable in the management of a plant.

The Rate of Filtration.

Normally, filter No. 20 was operated at a rate of 121 million gallons per acre daily. At times the rate was changed to 46 and 170 million gallons for the purpose of special studies. So far as could be learned a rate of 170 million gallons per acre daily, the highest which our devices would allow us to use, was fully as satisfactory as the normal rate, and there seems to be no reason, so far as the quality of the effluent is concerned, why even higher rates than 170 million gallons per acre daily could not be employed with safety. Conversely, there does not seem to be any practical gain in reductions of the rate to as low as 46 million gallons per acre daily.

In support of this the following summary of results is presented:

Comparison of the Qualitative Efficiency of Filtration at Different Rates.

Number of Runs.	Rate of Filtration.*	Grains of Chemical per Gallon.	Suspended Matters—Parts per Million.	Average Bacteria per Cubic Cen. in Effluent.	Average Bacterial Efficiency.
89, 92, 95, 100, 109, 111, 169, 170.	120	1.95	47	52	99.1
90, 93, 94, 101, 110, 112, 171, 172.	159	1.82	46	61	98.8
173, 174	48	2.33	58	36	99.6
175	120	2.25	51	90	98.9
172	154	2 28	78	80	99.6

* Million gallons per acre daily.

It goes without saying that in all cases it is necessary to have the application of chemical adjusted properly to the

character of the applied water. Within the limits studied the application of chemical was not found to be influenced by the rate of filtration.

The Regulation and Control of the Rate of Filtration.

In the regular operation of filter No. 20 by means of meter measurements and hand regulation of the valve on the outlet pipe, the rate of filtration did not vary more than plus or minus 5 per cent. The evidence does not indicate that these variations affected the quality of the effluent to an appreciable degree, if at all. In fact, on run No. 220 (see page 332) the rate was purposely fluctuated from time to time by about 25 per cent each side of the normal, and the effluent did not deteriorate in quality.

It appears that the most marked variations in rate were associated with changes in position within the sand layer of some of the stored materials removed from the water. This explains in part the irregularities in the loss of head observations as recorded for filter No. 20, in Appendix III.

For the operation of a large plant automatic regulators would doubtless be provided. To insure satisfactory results they ought not to allow of variations of more than about 5 per cent for a maximum.

Loss of Head.

Ten feet of head were used with filter No. 20, and in the case of the fine sand layer the loss of head was not a factor in connection with the quality of the effluent.

With the coarse sand the effluent repeatedly became unsatisfactory in character when the loss of head reached only from 6 to 7 feet.

The Washing of the Sand Layer.

With the regular practice of washing the sand layer with filtered water accompanied by agitation, until the wash water was practically free of stored coarse materials coming from the sand layer, it was found that, with both the coarse and fine sand layers, there was a deterioration as a rule in the bacterial character of the effluent for some five to fifteen minutes after the resumption of filtration.

The detailed evidence is presented in Appendix III, where it will be noted that in about one third of the runs there was no practical diminution in efficiency after washing. But on an average, made from 121 representative runs on which the data are complete, the effect was as is shown in the following table:

Sample of Effluent. Minutes after Washing.	Bacteria per Cubic Centimeter.	Bacterial Efficiency.
5	450	96.3
15	325	97.3
30	220	98.2
Average for run.....	190	98.5
Applied (subsided) water.....	12,200	.....

It is interesting to note that the average bacterial efficiency of the filter in the above table (98.5) is identical with that given on page 340 for the entire period of tests, exclusive of abnormal conditions. Combining subsidence and filtration, the above data correspond to bacterial efficiencies of about 98.5, 98.9, 99.3, and 99.4, respectively.

Viewing these data from a practical standpoint, in connection with a plant of sixty individual filters, such as would be required for the purification of the local water supply, it seems

very clear that the diminution in the efficiency would never be noticeable to the water consumer. The reason of this is that ordinarily only one or two filters would be washed at a time, and the effluent from them would be diluted by that from the other 59 (or 58) filters, so that the increase in bacteria in the effluent from the filters last washed would be almost if not entirely disguised by the dilution.

Under these circumstances it seems unnecessary to consider the wastage of the first portion of filtered water after washing, or steps to eliminate the deterioration at this particular time.

In this connection it may be stated that it occurred to us that possibly this deterioration might be due to the completeness with which the sand layer was washed. Accordingly, on December 27, the experiment was tried of washing the sand layer less perfectly than was normally the case. The results showed that this procedure did more harm than good.

The Agitation of the Surface of the Sand Layer for the Partial removing of Clogging.

This procedure was repeatedly tried, and was found to be a failure on quantitative grounds, as explained in the next section.

With the fine sand layer, however, it affected the quality of the effluent but very little. But in the case of the coarse sand layer a failure in the quality of the effluent repeatedly followed the agitation of the surface.

The Relation of Proper Attention and Supervision.

As is the case with any method or system of purification applicable to the variable Ohio River water at Cincinnati, this system demands for its successful operation skillful supervision

and attendance. This is shown conclusively by the table on page 342, recording the varying amount of required chemical day by day for 1898, when it is remembered that too little chemical means a poor bacterial grade of filtered water, and that too much chemical at times threatens the consumers with the possibility of undecomposed chemical in the filtered water, and means needless expense. Further discussion of this topic is unnecessary.

II.—ON THE PRACTICAL SIGNIFICANCE OF LEADING FACTORS AFFECTING THE COST OF CONSTRUCTION AND OPERATION OF AMERICAN FILTERS.

The factors considered here are substantially the same as those taken up under Section I.

The Composition of the Applied Water.

One of the important features of the Ohio River at Cincinnati, after plain subsidence for three days, is that it naturally contains a sufficient quantity of alkaline compounds to decompose the applied chemical; and thereby it obviates the expense of applying alkali, as was shown on page 346.

When the turbidity of the subsiding water becomes relatively great it increases the cost of construction and operation by the following means:

1. It requires more coagulating chemical.

2. It requires more provisions for coagulation and supplementary subsidence in order to clarify the water properly before it enters the sand layer.

3. It increases somewhat the percentage of wash water used in cleaning the filters.

4. It increases the cost of supervision and attendance.

The following table, repeated from page 341, illustrates the influence which increased amounts of suspended clay in the subsided water exerts upon the required quantity of chemical.

Table showing the Estimated Normal Amount of Chemical necessary for Different Grades of Subsided Water.

Grade of Subsided Water. Suspended Clay in Parts per Million.	Amounts of Sulphate of Alumina required in Grains per Gallon.
10	0.75
25	1.25
50	1.50
75	1.95
100	2.20
125	2.45
150	2.65
175	2.85
200	3.00
300	3.80
400	4.40

The significance, with reference to the percentage of wash water, of longer periods of coagulation and supplementary subsidence, with the applied chemical the same, at times of turbid water is shown by the following data, which are averages of actual runs made with the experimental system.

Suspended Clay in Parts per Million.	Applied Chemical in Grains per Gallon.	Period of Subsidence in Hours.	Percentage of Wash Water.
15	0.90	0.5	2.4
17	0.89	2.5	1.9
18	0.90	6.0	1.3
97	2.00	0.5	2.8
96	2.00	6.0	1.3
206	2.50	0.5	13.0
198	2.50	6.0	4.4

Reference to the different quantities of required chemical, as stated above, for the different grades of applied water, and the more frequent washings of the filter when the water was very turbid, are sufficient argument that the varying composition of the applied water is a factor of cost with regard to supervision and attendance.

The Application of the Chemical.

Kind.—While this method of purification does not require the use of any particular coagulating chemical, present evidence indicates sulphate of alumina to be the most practicable one for the purpose. In carload lots it can be purchased at present for about 1.4 cents per pound.

Method of Application.—Under the local conditions, both in the experimental plant and in the works at California, the use of dilute solutions discharged into the water by gravity under a constant head is satisfactory and comparatively cheap. It does not appear probable that it could be improved upon.

The Quantity of Applied Chemical.

Filter No. 20 was operated with an application of chemical estimated to be equivalent to an annual average of about 1.25 grains per gallon. The cost of this chemical is one of the chief factors in the total expense of purification.

While the effluent of this filter was almost uniformly brilliant and the bacterial results quite satisfactory under ordinary circumstances, yet it is felt that the superior bacterial results obtained with the application of a somewhat greater quantity of chemical would be justifiable and advisable, when the excellence and safety of the filtered water is judged from a high but at the same time practicable standpoint.

It is estimated that an annual average of 1.6 grains of sul-

phate of alumina per gallon of filtered water would be required to give uniformly a first-class effluent in all respects. The cost of this at current prices, as stated previously, would be $3.20 per million gallons of filtered water.

The Provisions for Coagulation and Supplementary Subsidence of the Plain Subsided Water after Chemical Treatment.

The supplementary basins used in connection with filter No. 20 provided for six hours as a maximum period of coagulation and subsidence, although the full period was availed of only at times of heavy freshets in the river. Specifically, of course, this added to the cost of purification, but it served to effect such important improvements in the construction and operation of this system that there is no room for doubt but that its use was a decided step in the direction of economy.

To offset the cost of its construction are a number of advantages resulting from its use, of which the following are the most important:

1. It would do away with the necessity of putting small basins under the filters, and thereby it would lessen the cost of the filters.

2. It would make it practicable to provide smaller reservoirs and a shorter period for plain subsidence, so far as purification alone is concerned.

3. It would reduce materially the percentage of wash water.

4. By virtue of the reduction in the frequency of washing and of the percentage of wash water, it would obviate the necessity of providing a reserve area of filters, to be used at times of turbid water.

5. So far as we could learn, the rate of actual application of chemical is not affected materially by the period of coagulation and supplementary subsidence; but through the change

in the percentage of wash water the net rate of application, based on the output of filtered water, would be reduced somewhat.

6. It would make the plant more manageable as well as smaller in size, and thus reduce the cost of supervision and attendance.

Each of these points seems to be sufficiently clear without further elaboration. But reference may be made to the effect produced upon the percentage of wash water by the period of coagulation, as shown by the tables presented at the beginning of this section (page 357) with regard to the composition of the applied water.

During these tests the periods of coagulation which were regularly employed from time to time, according to the turbidity of the subsided water, were 6.0, 2.5, and 0.5 hours, and occasional use was made of 0.1 hour as a matter of convenience by putting the chemical into the inlet pipe to the filter. With the fairly clear water obtained during the absence of heavy freshets, and covering the greater part of the year, 0.5 hour was found to be the best period to employ. At times of heavy freshets 6.0 hours were used to great advantage; but it does not appear that there are a sufficient number of days in a year when an intermediate period such as 2.5 hours could be employed with sufficient advantage to compensate for the expense which it would involve. Theoretically, however, the middle period would be advantageous on many occasions.

Concerning the practicability of divided applications of chemical during times of floods—that is, an application of chemical to the water at the entrance to the basin to facilitate subsidence, and again just before the water reached the filters—the evidence indicates that it would not lead to economy on many occasions. The reason of this lies in the fact that there is so small a dif-

ference with many kinds of turbid water between the amount of chemical necessary to bring about an appreciable amount of coagulation and that necessary for complete coagulation. This experience, which is rather limited, is at variance with earlier views, and more data are necessary before making a final decision.

There is one feature associated with a secondary application of chemical which is of much importance, and that is the opportunity which it affords of using a narrow margin with reference to the required amount of chemical (see page 357), and, if necessary, supplement it before the water goes on to the filters should it be too small to give satisfactory results. In this manner a considerable saving in chemical could be effected over conditions where this were not possible. It also has great significance in connection with the qualitative efficiency and precluding there being any excuse for furnishing a turbid and very poor quality of effluent, in the sense of only partial clarification and purification. This subject has already been referred to on page 350.

In this experimental plant the secondary application of chemical as a matter of convenience was made at the inlet pipe to the filter, giving about 0.1 hour as a period of coagulation. The evidence indicates that equally good results would follow if the application were made so that the period would be 0.5 hour, as in the case of fairly clear subsided water. It is unnecessary, therefore, to provide for a period of about 0.1 hour of coagulation.

Degree of Coagulation of the Water as it enters the Sand Layer.

The absence of well-defined, visible coagulation of the applied water as it enters the sand layer would probably affect the cost a little in an indirect manner by requiring a higher

grade of supervision, and the use of a safe margin in the application of chemical, according to the scheme outlined on page 357, which would tend to make the average rather higher than would be the case if a ready guide to the required quantity were constantly at hand.

The Construction of the Sand Layer.

The use, during the latter part of these tests, of a sand layer of more frictional resistance than was formerly the case led to a distinct gain in the uniform quality of the effluent; and it is believed that it was done without affecting materially the cost of purification. While it is true that the more resisting sand layer made the percentage of wash water greater under normal conditions, it also did away with those relatively short runs (with high percentages of wash water) due to the coagulated water "breaking through" the sand layer in places. It is believed that these differences would approximately compensate each other, practically speaking. To assist in this compensation, to the advantage of the sand layer of greater frictional resistance, would be the reduction in the required attendance.

A sand layer of greater frictional resistance may be obtained either by the use of a greater thickness of the sand used conventionally (about 0.42 mm. in effective size) or by a less thick layer of finer sand. As a matter of economy in the construction of a plant, the latter is preferable within reasonable limits. So far as could be learned, satisfactory results were obtained from twenty inches in thickness of a fine uniform sand of an effective size of 0.22 mm.; although, as stated, the quality of the effluent was improved at the sacrifice of some extra cost for wash water.

It is not clear that this is the best construction of the sand layer which is possible, and it is probable that in the construc-

tion of a large plant it would be best in part of the filters to provide for a 30-inch layer of a rather coarser sand, similar to the medium sand used with the original English filters here (see page 62); and if actual experience proved it to be thoroughly effective and more economical in the amount of wash water required, then replace the fine sand in the other filters with medium sand. To decide definitely where the line comes in regarding sand layers which will not allow the water to "break through" and give a turbid effluent, and which can be washed with the least water, requires additional data obtained from several filters operated side by side.

In passing, it may be stated that actual comparisons showed that with the same head the fine sand allowed the passage of about one half as much water as with the same thickness of coarse sand. From the effective sizes, 0.22 and 0.42 mm., one would expect only one quarter as great a flow of water, judged from the formula used in connection with the study of materials for English filters.

Kind of Sand.—The fine sand pumped from the bars in the river opposite Coney Island was found to be satisfactory; and this sand would be considerably cheaper than sand or quartz obtained from Minnesota or other distant places.

The Rate of Filtration.

This is an important element in the cost of purification, because it determines largely the size of the filter plant. Filter No. 20 was operated normally at a rate of 121 million gallons per acre daily, and there is no reason why a rate of 125 million gallons could not be used with satisfaction. This is 25 per cent higher than the normal rate, as previously and conventionally considered.

In this connection it is to be recalled that satisfactory results were also obtained at a rate of 170 million gallons per acre daily. With the same available head as used with 125 millions, the economic gain for the higher rate would not be as great as would appear, because the greater initial loss of head (following a wash) would reduce the quantity of filtered water per run, and would consequently increase the percentage of wash water. The question as to the most economical rate and head to employ is discussed as a separate topic just beyond, following the one on the loss of head.

The Regulation and Control of the Rate of Filtration.

In practice, economy in operation demands that meter and hand regulation of outlet valves used on this filter should be replaced by automatic controllers. It is believed that the latter are perfectly practicable, with a required head of only a few inches to operate them; but in these tests no information of value upon this point was obtained.

The Loss of Head.

In the normal operation of filter No. 20 the total available head employed, measured from the water level above the sand layer to the mouth of the outlet pipe, was 10 feet. Of this distance, 4.33 feet was above the strainer system, and 1.83 feet and 2.67 feet were above the top of the 30-inch coarse sand layer and the 20-inch fine sand layer, respectively.

It will be noted at once that successful use with this filter was made regularly of a negative head, which was found to be a failure in the English filters. This is explained, so far as we have been able to learn, by distinct differences in the two types of filters, as follows:

In English filters the section of maximum frictional resistance is always at and just below the surface of the sand layer. Accordingly, when the acting head exceeds the depth of water above the sand, there is a united clogging action at this portion of the filter, due both to suspended matters removed from the water and the air evolved from it. As a result of the combined action, the yield of water after this time is very small.

But in American filters of this construction the section of maximum frictional resistance is at the strainers located at the bottom of the sand layer until the filter has ordinarily been in operation for a large percentage of the length of the run between washings. Furthermore, the clogging at the surface is relatively much slower than in the case with English filters, because the higher velocity in the American filters carries considerable portions of the suspended matters further down into the sand layer. Consequently, we find primarily that in American filters negative heads with the evolution of air do not occur until the acting head has reached the depth of water above the sand plus the thickness of the sand layer. For some distance beyond this the acting head can be carried before the section of the filter near the surface of the sand layer becomes the one of maximum frictional resistance. Until this time arrives, negative heads evolve air in American filters at the bottom of the sand layer (which is kept from rising apparently by the velocity of flow), and thus defer the time when suspended matters from the water and the evolved air combine at the same portion (upper) of the sand layer to cause very rapid clogging.

From an economical standpoint negative heads are an advantage because they obviate wastage and delay in the removal of considerable quantities of water above the sand layer, just prior to washing. To make negative heads a success, it is

necessary to make the strainer system the section of greatest frictional resistance, as explained above.

Relative to the maximum available head which it is most economical to employ, the evidence indicates that 10 feet was substantially correct for the 30 inches of coarse sand, but that it would be about 12 feet for the 20-inch layer of fine sand, although, with the latter, 10 feet (which was actually used) was practicable.

With the coarse sand layer the initial loss of head at the normal rate was 2.3 feet, while it was 5.0 feet for the fine sand layer. According to the available local evidence, the loss of head can be carried economically to about 7 feet in excess of the initial loss of head. Representative data obtained with the coarse sand layer upon this point are as follows:

Percentages of the Total Water Filtered between Washings which were Filtered on an average for each successive Foot Increase in Loss of Head.

		Total Loss of Head — Feet.						
		3–4	4–5	5–6	6–7	7–8	8–9	9–10
Percentage of Total Effluent.	Series A*....	13.0	12.6	14.3	12.2	13.7	12.2	10.2
	Series B*....	18.5	17.8	17.0	18.1	14.2	10.1	3.5
	Series C*....	13.1	17.2	17.8	17.0	17.0	12.1	4.1
	Average.....	14.9	16.5	16.4	15.8	15.0	11.4	6.6

*Suspended matters in plain subsided water: Series A, 10 to 50 parts per million; Series B, 51 to 100 parts per million; Series C, 100 to 250 parts per million.

These data on an average show clearly, after the total loss of head reached about 7 feet more than the initial loss of head, that there was a very notable decrease in the yield of effluent per foot of head.

On the Economical Limits to which the Rate of Filtration and Loss of Head can be carried in American Filters.

It has already been shown that with the fine sand the increase in loss of head above the initial could be carried economically to about 7 feet (12 feet total) at a rate of 120 million gallons per acre daily. The records of runs Nos. 173 and 174 at rates of 46 and 51 million gallons per acre daily, respectively, indicate that at these rates the economical increase above the initial would be about 9 feet, or 2 feet more than at the 120 million gallon rate. It seems reasonable to conclude, therefore, that the economical increase at rates higher than 120 million gallons per acre would not be more than 7 feet, and perhaps it would be less.

The increased cost of pumping for the extra head is very small in comparison with the gain made by longer periods between washings, not only in the cost of the wash water, but also in the cost of supervision and incidentally in the deterioration of the filtered water with filters just after washing. Economy demands that the full increase in loss of head which is efficient should be provided.

It may be concluded that high rates are more economical than low ones, and that the full head which can be used efficiently should be provided. Just where the economical limit of the rate of filtration is can only be determined from practical experience with a wider range of conditions than existed here, but there seems to be no indication that the capacity of a plant originally constructed on a medium rate basis (100 to 125 million gallons per acre daily) could not readily and economically be increased, as the consumption demanded, to rates at least as high as the highest tried here (170 million gallons per

acre daily), provided the full economical increase in loss of head could be obtained.

The Washing of the Sand Layer.

The evidence indicates that the general method employed in washing the sand layer, as described in Chapter VIII, page 304, was practically as economical and efficient as could be expected. The principal features in this connection are reviewed briefly as follows:

Distribution of Wash Water.—The slotted brass strainer cups (furnishing the exit area for the filtered water) served reasonably well in distributing the wash water uniformly, except that there was no tendency for the water to pass to the portions of the sand layer at the bottom between the cups. This left small portions of the sand layer rather conical in shape between the strainers, with no sure means of being cleaned. Steps should be taken to remedy this.

Rate of Application.—Normally with the coarse and fine sand layers the wash water was applied at the rate of 460 and 330 million gallons per acre daily. In the case of the fine sand this rate could not be exceeded by more than about 25 per cent, otherwise the loss of sand into the sewer would be prohibitive.

Pressure of Wash Water.—The gross pressure of the wash water at the bottom of the filter when applied at the regular rates was substantially 14.50 feet (6.3 pounds). Deducting from this the water column within the filter, the net pressure was 9.78 feet.

Agitation of the Sand.—The agitation of the sand layer during washing is an advantage, and it would be apparently a further gain to be able to lower the rake teeth very nearly to the bottom of the filter. In filter No. 20 the distance between the lowest point reached by the rake teeth and chain

attachment was 6.5 inches above the top of the strainers and 8.0 inches above the bottom of the filter tank. As stated above, provisions should be made for reaching the sand at the bottom of the layer to give it a thorough washing, even if it were found to be unnecessary or undesirable to do so regularly.

Power used for Agitation.—It is estimated that the power required to operate the agitator of filter No. 20 was about 0.33 horse-power. On this basis, which seems to be a fair one, about 13 horse-power would be required for a filter 25 feet in diameter.

Percentage of Wash Water.—According to the available evidence, with a layer of fine sand under the conditions of operations employed with filter No. 20, it is estimated that the percentage of filtered water required for washing would range from 4 to 9 and average about 5 per cent. With the 30 inches of coarse sand, these figures would apparently become 2, 6, and 3, respectively.

Time required for Washing.—The evidence indicates that on an average 30 minutes were required for washing the filter with a fine sand layer, from the closing until the opening of the outlet valve. Of this time the application of wash water would continue about 25 minutes. The balance of the time would be required in filling the compartment above the sand with the applied water. With coarse sand the time of washing was 20 minutes.

Frequency of Washing.—With the different grades of applied water, it is estimated that the filter with fine sand would be washed once in 8 to 24 hours, the average length of run being about 15 hours. If a layer of coarse sand was employed, these periods would become approximately 6, 36, and 20 hours, respectively.

Disposal of Wash Water.—During the operation of filter No. 20 the wash water as it left the filter was regularly discharged into the sewer. But experiments made in the laboratory show that the great bulk of the suspended matters, including the bacteria, are removed by plain subsidence in less than one day. Further, that probabilities of growths of bacteria in the water are exceedingly remote. Under these circumstances it seems very likely that it would be an advantage to make provisions for pumping (with a reserve wash-water pump) the wash water into the force main leading to the subsiding reservoirs. Here the main bulk of the suspended matters and bacteria would be removed, and it is doubtful whether the subsided water would show any sign of its presence.

A gain would be hereby effected, because, owing to the relatively high elevation of the filter plant, it would be cheaper to pump from this point to the basins than it would be from the river to the basins, and it could be done with no increase in the cost of the plant and only a nominal expense for operation.

Wastage of Filtered Water.—As stated on page 354, the quality of the filtered water directly after washing was somewhat inferior to the normal; but the evidence indicates clearly that in a large plant it would not be necessary or desirable to waste any of the filtered water.

Taking every thing into consideration, it is believed that the method of washing is practicable and reasonably satisfactory, but that there is an opportunity of reducing its cost by the use of a somewhat coarser sand than the last size employed.

The Agitation of the Surface.

Surface agitation was only a very moderate success at occasional intervals in the case of the coarse sand, and was a failure, practically speaking, in the case of the fine sand. The reason

of this seemed to be that the particles in the water were so small that they penetrated deep into the sand layer, so that the section of sand which was thoroughly clogged extended much below the immediate surface. This experience, it is to be stated, was obtained in the face of the removal by temporary devices of the muddy water from above the sand after agitation.

During about four months of the year the river water is of such a character that it could be purified with advantage without going to the expense of pumping it into the subsiding reservoirs. Under these circumstances there is considerable probability of making successful use of surface agitation; and it ought not to be lost sight of in the construction of the plant.

The Relation of Proper Supervision and Attendance.

With a 60-million-gallon plant operated to clarify and purify the variable Ohio River water at Cincinnati, where the daily range in the cost of chemical (sulphate of alumina) alone would be from $84 to $480, according to present prices, it is imperative, on the ground of economy as well as safety, that the plant should be well managed; and this point is too obvious to admit of detailed discussion.

III.—RESUMÉ WITH AN OUTLINE OF CONDITIONS FAVORING THE MOST EFFICIENT AND MOST ECONOMICAL PURIFICATION BY THIS METHOD.

The leading points in this connection, based upon the results of these investigations, are taken up briefly, as follows:

Preliminary Treatment of the River Water.

Plain subsidence of the river water for three days is fully as long preliminary treatment as it is practicable to give to this water. In fact, with an adequate coagulating and supplement-

ary basin, it is very doubtful whether it is advisable to provide a period of more than one day, except for reasons independent of the purification of the water. This subject is dealt with further in Chapter X, where there are presented comparisons of cost.

At times, however, it is clear that it would be advantageous not to use the plain subsiding reservoirs, but deliver the fairly clear river water directly to the coagulating basin, and thus reduce the cost of pumping.

Application of Chemical.

Kind.—At present, sulphate of alumina is apparently the most suitable chemical to apply for the coagulation of this water. If a more advantageous chemical were found it could probably be employed without the necessity of changes of serious importance.

Method of Application.—Under the local conditions a gravity discharge of a weak chemical solution under a constant head would be most advisable, as was used in these tests.

Places of Application.—The evidence indicates that at least two different places of application should be provided; and it is likely that at times a third and intermediate place could be used to advantage, but with questionable economy. (See page 360.) These three places would represent about 0.5, 2.5, and 6.0 hours, respectively, as the average period of flow from the point of application to the entrance of the water into the filters. At no time, however, would the chemical be applied at more than two places at once; and the middle one of the periods stated could be omitted to best advantage if only two should be provided.

Regulation of Flow.—Owing to the corrosive action of solutions of sulphate of alumina, the required tanks, pipes,

and fittings should be of material not subject to this corrosive action. To regulate the flow meters with complete hard rubber linings should be used.

Provisions for Coagulation and Supplementary Subsidence.

The evidence appears to be very decisive that a period equivalent to at least six hours' flow should be provided, with places for the application of chemical, as mentioned above.

Buildings.

It would be necessary to provide a suitably heated and lighted building to cover the filters, and also adequate buildings for the chemical appurtenances, storage of chemical, engine and boiler-rooms, coal shed, laboratory, and office.

Structure of Filters.

In the present state of development it appears that filters constructed of steel with proper protective coatings would be sufficiently permanent for practical purposes. The use of wood is regarded as inadmissible.

Size of Filters.

The larger the filter the less expensive would be the operation of the plant, and there seem to be no reasons why filters 25 feet in diameter could not be used with advantage.

Amount of Head Required.

The evidence at present shows that about 12 feet represents the economical limit to which the total loss of head can be carried under all circumstances. However, 10 feet would be practicable and a reasonably satisfactory head, but would make the percentage of wash water rather higher than necessary in

the event that fine sand and higher rates than those stated below were used.

Rate of Filtration.

Normally a rate of 125 million gallons per acre daily could be satisfactorily employed, and the evidence shows clearly that rates distinctly higher than this could be safely used on special occasions and also to meet the increased consumption of water.

To locate the maximum limit definitely at this time appears to be unwise, in the absence of the more decisive evidence which would be secured in practice.

Regulation of Rate of Filtration.

This can best be done by having a free gravity flow of the water on to the filters, and having the rate of flow regulated by automatic controllers placed at the outlet pipes.' The question of the most suitable form of controller for filters of the size stated is one which requires further study and development.

Washing the Sand Layer.

The method of washing with filtered water, with accompanying agitation, until the sand layer is comparatively clean, as has been described and discussed (page 368), is as satisfactory as seems practicable to obtain in the light of present evidence.

Height of Filters.

By eliminating the coagulating basins from immediate connections with and as a part of the individual filters, a height of five feet is ample when a negative head is employed, except as required to provide for different levels of the applied water.

Character of the Sand Layer.

The use of 20 inches of fine sand from the bar in the river opposite Coney Island was found, on the whole, to be superior to the coarse sand formerly in use. It is an open question, however, whether, it is not possible to secure very nearly as good results with 30 inches of sand of an intermediate size, and thus reduce the percentage of wash water.

Under these circumstances it would be advisable, in our judgment, to provide for a thickness of 30 inches in all cases, and in half of the filters use 20 inches of fine sand and in the other 30 inches of medium sand. As the river sand is comparatively inexpensive, a change could be ultimately made to the sand layer which extended experience proved to be better.

Filtered Water Exits.

The available evidence indicates that it is not practicable to use perforated discs or plates capable of supporting fine sand. This being true, the use of slotted strainers is apparently necessary. The ones in use would clearly become clogged in time, so that it would be necessary to remove them for cleaning from time to time or to replace them.

As has been pointed out already, the strainers should be arranged, if possible, to allow all of the sand to be washed and reached by the teeth of the agitator.

Agitation of the Surface of the Sand Layer.

Although surface agitation could not be used with satisfaction when treating the subsided water, it seems possible to use it to advantage when the river water is sufficiently clear to allow the omission of plain subsidence. Accordingly, this should be borne in mind in the construction of the filter tanks and the agitators.

Disposal of Wash Water.

There seems to be an opportunity for economy with no corresponding disadvantages, by pumping (at least at times) the wash water after it leaves the filter into the force main leading to the plain subsiding reservoirs. (See page 370.)

Accessibility of Parts.

To facilitate examination and repairs, the principal parts, notably the strainer system, should be made as accessible as is practicable.

Final Conclusions.

The evidence shows that the American system of purification is applicable to the Ohio River water at Cincinnati, based on the efficiency and cost of its operation.

CHAPTER X.

Final Resumé and Conclusions.

Eliminating from consideration in this chapter, for the most part, those points of a purely technical nature which have been discussed at length earlier in this report, the facts of practical significance learned during these investigations may be summed up as follows:

Inapplicability of English filters to the clarification and purification of the unsubsided Ohio River water at Cincinnati.

In the purification of those classes of water for which the English type of filters is strictly applicable, the available evidence indicates clearly that this method is a satisfactory one when the filters are properly constructed and operated. Further, so far as our knowledge goes, this method is ordinarily somewhat more efficient and more economical for water for which it is readily applicable than any other process of purification which has received serious attention.

But in the consideration of this method of purification with reference to the river waters of the central west, where frequent freshets cause the water to be laden with comparatively large amounts of silt and clay, it is found that English filters have decided limitations in their applicability.

At the outset of these investigations the position was taken, endorsing the recommendation of the Engineer Commission, that the Ohio River water at Cincinnati should receive a preliminary treatment by plain subsidence to prepare the water for clarification and purification by English filters. Expe-

rience in the operation of the fifteen original experimental filters of the English type showed the wisdom of this step, because the suspended matter in the river water would increase materially the cost of treatment, and, of still greater importance, would preclude at times the possibility of securing filtered water of satisfactory appearance and character.

For the sake of explicitness it is desired to show, with the data of the fairly normal year of 1898, the proportion of the time when English filters would be inapplicable in the purification of the unsubsided Ohio River water at Cincinnati. This necessitates fixing an average limit of permissible suspended matter in this river water, and is a difficult matter from present evidence.

In part this is due to variations in the character and in the relative amounts of the suspended silt, clay, and organic matter; and in part it is due to different amounts of clay stored in the sand layer, which affects materially the capacity of the filter to retain the clay of the applied water. During these investigations the unsubsided river water was not regularly applied to filters; and, with the exception of the results of tests for a few days only, it is necessary to depend upon general information obtained with reference to this point. So far as our information goes, it appears that an average of 125 parts per million is a conservative estimate of the amount of suspended matters in the unsubsided river water, which could be regularly and fairly satisfactorily handled by English filters. But at times this estimated average would be too low, and at other times too high.

It is seen from the following table containing the daily amounts of suspended matter in the unsubsided river water for 1898, that the above stated limit was exceeded during the greater part of the year.

Table showing the Parts per Million of Suspended Matter in the Unsubsided Ohio River Water at Cincinnati for each Day of the Year 1898.

Day	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1.....	200	150	150	126	380	193	194	394	110	40	334	100
2.....	250	248	43	118	274	184	111	324	82	36	180	112
3.....	500	372	100	182	122	217	95	316	75	32	150	50
4.....	400	184	125	152	130	124	76	325	72	40	120	100
5.....	300	134	114	155	137	140	110	336	79	18	115	500
6.....	200	113	100	312	147	149	140	405	60	44	110	455
7.....	700	108	80	283	419	72	165	867	50	39	118	300
8.	800	96	57	158	312	70	78	1000	45	33	120	205
9.....	1200	88	100	390	305	64	94	1255	39	27	300	250
10.....	2333	172	220	164	312	64	76	800	29	51	504	247
11.....	1151	237	310	191	207	45	65	1000	100	63	426	200
12.....	1024	401	393	154	250	42	60	1321	46	54	306	150
13.....	719	377	330	194	216	74	58	641	57	46	500	111
14.....	578	182	230	97	122	76	52	410	28	60	600	75
15.....	470	425	102	91	150	79	70	182	36	24	500	37
16.....	433	262	175	115	179	35	81	379	130	31	394	34
17.....	416	246	406	86	133	37	76	550	42	38	281	31
18.....	308	236	684	101	99	39	70	681	28	39	230	30
19.....	320	192	300	150	171	37	244	504	100	40	187	40
20.....	330	413	500	251	394	68	370	533	170	41	209	1130
21.....	358	293	782	67	398	100	320	400	241	38	181	295
22.....	285	147	479	77	310	130	274	277	257	35	170	400
23.....	401	310	478	75	322	160	175	267	123	55	160	350
24.....	535	221	534	150	218	194	120	537	110	144	157	311
25.....	522	332	474	251	109	151	173	700	95	492	130	350
26.....	601	170	307	58	313	152	390	580	81	599	101	370
27.....	533	123	320	72	205	153	609	429	117	414	98	374
28.....	292	141	325	223	174	154	924	360	90	369	98	250
29.....	269	.....	334	290	184	221	271	250	69	292	96	170
30.....	207	.....	250	446	154	243	360	205	50	215	94	230
31.....	57	....	140	.....	204	.....	450	138	.....	274	.....	301

On the above stated basis of differentiation between waters for which English filters are applicable or inapplicable, it is found that during the year 1898 these filters could have been used satisfactorily without preliminary subsidence of the local river water on only 132 days, or 36 per cent of the total time. In the light of this evidence it goes without saying that English filters would be a failure in the treatment of the unsubsided water of the Ohio River at Cincinnati.

It is instructive to note in this connection that, owing to the variations in the composition of the river water, English filters without subsidence would be applicable to the local river water only for short periods of time. In fact, they could not have been used with success for ten days at a time in 1898, except during the months of June, July, September, and October. This is shown more clearly by the following table, in which the letter "F" is recorded for each day on which English filters would thus fail, and the letter "S" for those days when these filters would be applicable, on the above stated basis of differentiation. In the actual filtration of the unsubsided local river water, differences in the amount of clay stored within the sand layers at the beginning and at the end of prolonged freshets would doubtless cause slight modification in the following table; but, in the aggregate, the available evidence indicates this classification to be substantially correct.

Table showing the Number and Distribution of Days in 1898 when English Filters were Applicable to the Clarification and Purification of the Unsubsided Ohio River Water at Cincinnati.

DAY	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1.....	F	F	F	F	F	F	F	F	S	S	F	S
2.....	F	F	S	S	F	F	S	F	S	S	F	S
3.....	F	F	S	F	S	F	S	F	S	S	F	S
4.....	F	F	S	F	F	S	S	F	S	S	S	S
5.....	F	F	S	F	F	F	S	F	S	S	S	F
6.....	F	S	S	F	F	F	F	F	S	S	S	F
7.....	F	S	S	F	F	S	F	F	S	S	S	F
8.....	F	S	S	F	F	S	F	F	S	S	S	F
9.....	F	S	S	F	F	S	S	F	S	S	F	F
10.....	F	F	F	F	F	S	S	F	S	S	F	F
11.....	F	F	F	F	F	S	S	F	S	S	F	F
12	F	F	F	F	F	S	S	F	S	S	F	F
13.....	F	F	F	F	F	S	S	F	S	S	F	S
14.....	F	F	F	S	S	S	S	F	S	S	F	S
15.....	F	F	S	S	F	S	S	F	S	S	F	S
16.....	F	F	F	S	F	S	S	F	S	S	F	S
17.....	F	F	F	S	F	S	S	F	S	S	F	S
18.....	F	F	F	S	S	S	S	F	S	S	F	S
19.....	F	F	F	F	F	S	S	F	S	S	F	S
20.....	F	F	F	F	F	S	F	F	F	S	F	F
21.....	F	F	F	S	F	S	F	F	F	S	F	F
22.....	F	F	F	S	F	F	F	F	F	S	F	F
23.....	F	F	F	S	F	F	F	F	F	S	F	F
24.....	F	F	F	F	F	F	S	F	S	F	F	F
25.....	F	F	F	F	S	F	F	F	S	F	F	F
26.....	F	F	F	S	F	F	F	F	S	F	S	F
27.....	F	S	F	S	F	F	F	F	S	F	S	F
28.....	F	F	F	F	F	F	F	F	S	F	S	F
29.....	F	.....	F	F	F	F	F	F	S	F	S	F
30.....	F	.....	F	F	F	F	F	F	S	F	S	F
31.....	S	.....	F	....	F	.....	F	F	.....	F	.....	F

INAPPLICABILITY OF ENGLISH FILTERS IN THE CLARIFICATION AND PURIFICATION OF THE OHIO RIVER WATER AT CINCINNATI AFTER PLAIN SUBSIDENCE FOR THREE DAYS.

Plain subsidence for three days, as was found by the results of this investigation which are recorded in Chapter III, causes on an average a removal of practically 75 per cent of the suspended matters present in the local river water. Accordingly, a system of purification comprising plain subsidence for three days and English filtration is applicable for water containing more suspended matter than is the case with English filters without subsidence.

The efficiency of plain subsidence in the preparation of very turbid waters for satisfactory filtration through filters of the English type, however, is not so great as would appear at first sight. The reason of this is that the clay particles remaining in the turbid subsided water are more difficult to handle than an equal weight of the mixed silt and clay of the original river water.

While English filters are able to remove satisfactorily on an average about 125 parts of silt and clay of the unsubsided water, actual experience (see Chapter V, Section 1) shows that they can regularly handle suspended clay in subsided water in amounts ranging only as high as from 30 to 70 parts (depending largely upon the amount of the clay stored in the sand layer), and averaging about 50 parts per million. But it is true that for two or three days on short rises in the river, or at the beginning of long freshets, the retentive capacity of the sand layer allows of satisfactory results with the clay in the applied water considerably in excess of 70 parts. If this capacity is greatly overtaxed, however, the advantage is merely temporary, as the stored clay is washed out later, producing markedly turbid effluents.

The next table shows the composition during 1898 of the Ohio River water with reference to suspended matters, after plain subsidence for three days on the basis of an average removal of 75 per cent:

Table showing the Parts per Million of Suspended Matter in the Ohio River Water at Cincinnati, after Plain Subsidence for Three Days, for each Day of the Year 1898.

Day	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1.....	50	38	37	31	95	48	48	98	27	10	84	25
2.....	62	62	11	30	68	46	28	81	20	9	45	28
3.....	125	93	25	45	30	54	24	79	19	8	37	12
4.....	100	46	31	38	32	31	19	81	18	10	30	35
5.....	75	33	29	39	34	35	27	84	17	12	29	125
6.....	50	28	25	78	37	37	35	100	15	11	27	114
7.....	175	27	20	71	105	18	41	217	12	10	30	75
8.....	200	24	14	40	78	17	19	250	11	8	30	51
9.....	300	22	25	97	76	16	24	320	10	7	75	62
10.....	580	43	55	41	78	16	19	200	7	13	126	62
11.....	290	59	77	48	52	11	16	250	25	16	106	50
12.....	255	100	98	38	62	10	15	330	11	14	76	37
13.....	180	94	82	48	54	18	14	160	14	11	125	28
14.....	144	45	57	24	30	19	13	102	7	15	150	19
15.....	118	106	25	23	37	20	18	45	9	6	125	9
16.....	108	65	43	29	45	9	20	95	32	7	98	8
17.....	104	61	102	21	33	9	19	138	10	9	70	8
18.....	77	59	171	25	25	10	18	170	7	10	57	7
19.....	80	48	75	37	43	9	61	126	25	10	47	10
20.....	82	103	125	63	98	17	92	133	42	10	52	282
21.....	89	73	196	17	99	25	80	100	60	9	45	74
22.....	71	37	120	19	77	32	68	69	64	9	42	100
23.....	100	77	119	19	81	40	44	67	31	14	40	87
24.....	134	55	134	37	55	48	30	134	27	36	39	78
25.....	131	83	118	63	27	38	43	175	24	123	32	87
26.....	150	42	77	17	78	38	97	145	20	150	25	92
27.....	144	31	80	18	51	38	152	107	29	103	24	93
28.....	73	35	81	56	43	39	231	90	22	92	24	62
29.....	67	.....	83	72	46	55	68	62	17	73	24	42
30.....	54	.....	62	111	38	61	90	51	12	54	23	57
31.....	14	.....	35	.....	51	.....	112	35	.....	68	.....	75

Taking an average amount of 50 parts of suspended clay in the subsided water as the basis of differentiating those days

in 1898 when English filters could have satisfactorily clarified and purified the local water after plain subsidence for three days, it is found that these days amount to 197, or 54 per cent of the total time. But, practically speaking, English filters would have been satisfactory in the treatment of the subsided water on more than 197 days in 1898, because the capacity of the sand layer to hold back the applied clay would cause the elimination from the days of failure of those occasions when there were freshets of short duration in the river; that is to say, the capacity of the filters to store clay within the sand layer would allow for a short time applications of clay much in excess of the amounts which could be regularly handled. Based on actual results of operation of the experimental filters, it is estimated that during the year 1898 English filters could have been used with satisfaction in the clarification and purification of the subsided water on 231 days, or 64 per cent of the total time.

While in some instances it is true that the decision as to whether or not the effluent was satisfactory might not coincide with the views of every one, yet, as a rule, the conditions were such as to preclude differences of opinion. In unqualified terms it can be stated that plain subsidence for three days is insufficient to prepare uniformly the Ohio River water at Cincinnati for successful clarification and purification by means of filters of the English type.

For the sake of a clear understanding of the irregular and prolonged intervals during which these conditions would be unsatisfactory, the following table is presented showing those days on which the system would apparently be a failure (marked F) and those days on which it would apparently be successful (marked S), based on the experience of these investigations, as shown in Chapters IV and V.

In the preparation of this table, recognition was made of the influence which was found during the test to be exerted by the retentive capacity of the sand layer upon the amount of clay which could be removed, especially at times of short freshets, and at the beginning and the end of rises of long duration.

Table showing the Number and Distribution of Days in 1898 when English Filters were Applicable to the Clarification and Purification of the Ohio River Water at Cincinnati, after Plain Subsidence for three Days.

Day.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1.....	S	F	S	S	S	S	S	F	S	S	F	S
2.....	S	F	S	S	S	S	S	F	S	S	F	S
3.....	S	F	S	S	S	S	S	F	S	S	F	S
4.....	F	S	S	S	S	S	S	F	S	S	S	S
5.....	F	S	S	S	S	S	S	F	S	S	S	S
6.....	F	S	S	S	S	S	S	F	S	S	S	F
7.....	F	S	S	S	S	S	S	F	S	S	S	F
8.....	F	S	S	S	S	S	S	F	S	S	S	F
9.....	F	S	S	S	S	S	S	F	S	S	S	F
10.....	F	S	S	S	S	S	S	F	S	S	F	F
11.....	F	S	S	S	S	S	S	F	S	S	F	F
12.....	F	S	S	S	S	S	S	F	S	S	F	F
13.....	F	S	S	S	S	S	S	F	S	S	F	S
14.....	F	S	S	S	S	S	S	F	S	S	F	S
15.....	F	S	S	S	S	S	S	F	S	S	F	S
16.....	F	F	S	S	S	S	S	F	S	S	F	S
17.....	F	F	S	S	S	S	S	F	S	S	F	S
18.....	F	F	F	S	S	S	S	F	S	S	F	S
19.....	F	F	F	S	S	S	S	F	S	S	F	S
20.....	F	F	F	S	S	S	S	F	S	S	F	S
21.....	F	F	F	S	S	S	S	F	S	S	F	F
22.....	F	F	F	S	S	S	S	F	S	S	F	F
23.....	F	F	F	S	S	S	S	F	S	S	F	F
24.....	F	F	F	S	S	S	S	F	S	S	F	F
25.....	F	F	F	S	S	S	S	F	S	S	F	F
26.....	F	F	F	S	S	S	S	F	S	F	S	F
27.....	F	S	F	S	S	S	S	F	S	F	S	F
28.....	F	S	F	S	S	S	F	F	S	F	S	F
29.....	F	.....	F	S	S	S	F	F	S	F	S	F
30.....	F	.....	F	S	S	S	F	F	S	F	S	F
31.....	F	.....	S	.....	S	....	F	F	.....	F	.....	F

SPECIFIC DIFFICULTIES AND COMPLICATIONS IN THE TREATMENT OF THE LOCAL RIVER WATER BY PLAIN SUBSIDENCE AND ENGLISH FILTRATION.

It is necessary in this review to call attention to several abnormal characteristics of importance which appeared in the study of the local water, as follows:

1. The comparative absence of organic matter in the water capable of forming gelatinous films around the sand grains at times when it was needed most. This was apparently due in part to the removal of the organic matter by attachment to sand and silt deposited in the river, and in part to further removal in the subsiding tank.

2. The minuteness of the clay particles in the subsided water, and difficulties in retaining them at and near the surface of the sand layer, especially in the comparative absence of organic matter adapted to increasing the retentive capacity of the sand.

3. The disturbances of the surface of the sand layers, and consequent irregularities in the rate of filtration, due to fishes, earth-worms, and other forms of animal life.

Of these three objectionable features, which, so far as our knowledge goes, are not met to any corresponding degree in water actually treated with success by this system of purification, the first two are inherent ones, incapable of ready correction by artificial means, while the third one can be controlled more or less by a proper use of screens. It is by no means certain, however, that screens would remove sufficiently the spawn of fishes or the eggs of angleworms.

FEATURES WHEREIN PLAIN SUBSIDENCE FOR THREE DAYS AND ENGLISH FILTRATION FAIL ESSENTIALLY IN THE CLARIFICATION AND PURIFICATION OF THE LOCAL RIVER WATER.

The system of purification under consideration was unsatisfactory along three lines, as follows:

1. At times of prolonged freshets the turbidity of the filtered water was so great that it had the brownish appearance of the unfiltered water, frequently containing over 30 parts per million of suspended clay, an amount and of a character which makes it doubtful whether it could be removed by a second filtration.

2. At times of freshets the penetration and retention of the clay within the main body of the sand layer would make the cost of scraping greater, and would apparently necessitate the reconstruction of the entire sand layer at much more frequent intervals than is normally the case in present practice with this type of filter.

3. When the filtered water was turbid and brownish for some little time there was a marked tendency towards a diminution in the bacterial efficiency of the filters. During the long freshets frequently occurring during the winter the evidence points to the matter as one of serious significance.

The second of these points might be tolerated, if no way could be found to obviate it; but the first and third of these points may be safely stated as prohibitive, in the absence of any practicable means of assisting the filters at such times.

IMPRACTICABILITY OF FURTHER PREPARATION OF THE LOCAL RIVER WATER FOR TREATMENT WITH ENGLISH FILTERS BY PLAIN SUBSIDENCE BEYOND ABOUT THREE DAYS.

As these investigations showed that English filters are a failure locally, owing chiefly to insufficient preparation of

the river water at times of freshets, the next logical step is to consider the best means of securing more efficient preliminary treatment of the river water. To obtain this by extending the average period of plain subsidence beyond about three days would not be practicable, on the ground of cost, for the following reasons:

1. Experience shows that the fine clay particles remaining in water which has been subsided for three days subside very slowly, and the increase in the percentage of suspended matters removed is seldom more than 5 for any day beyond the third, and decreases steadily as the period of subsidence is extended. This is shown clearly by the data presented in Chapter III, and is confirmed by the casual observations and analyses made in connection with the efficiency in clarifying the same river water, of the subsiding reservoirs of Covington, where the period of subsidence is about thirty days. On February 20, 1898, a sample of water collected from the outlet of the lower Covington reservoir was found to contain 52 parts of suspended clay.

2. The cost of adequate preliminary treatment of the water by this procedure would be disproportionately high, because this amount of preparatory treatment would be required less than half of the time, while the fixed charges for the interest and sinking fund on the cost of constructing the required subsiding reservoirs would be constant.

Under these circumstances economy demands the consideration of other preparatory methods, to be used either with or without the assistance of plain subsidence.

IMPERATIVENESS OF THE USE OF COAGULANTS.

The present evidence is conclusive that the large quantities of very minute clay particles, present in the local river water

for periods ranging probably from three to six months in different years (and averaging about four months), can not be removed in a practicable manner in their original condition by subsidence and by filtration through English filters. So far as present knowledge upon this subject goes, there is only one way in which these clay particles can be removed, and that is to apply a chemical which shall aggregate them into flakes or masses, so that it is practicable to remove them subsequently by subsidence and filtration.

In the light of these facts it can be stated in unqualified terms that, for the practical clarification and purification of the local river water, it is imperative at certain seasons of the year to make use of a chemical having the power to aggregate the clay particles.

PRACTICABILITY OF THE USE OF COAGULANTS.

In connection with the satisfactory treatment of the local water the use of coagulants is practicable for the following reasons:

1. Coagulants are capable of affording the water a safe and satisfactory preparation prior to subsidence or filtration, or both, with a comparatively small expense for chemical devices.

2. Coagulation may be secured with comparatively inexpensive chemicals.

3. The total cost of coagulation in the modified English system comes within reasonable limits, because the principal item of cost, the coagulating chemical, is a prime factor only when the character of the water requires its use. That is to say, during half of the year and more, when coagulation is not imperative with this system, the cost would be merely nominal for fixed charges on the required portion of the plant devoted to chemical devices; and with the American system

the advent of very turbid and difficult water to handle means simply an increase, practically speaking, in the amount of chemical.

THE MOST SUITABLE COAGULATING CHEMICAL AND ITS BEHAVIOR WHEN APPLIED TO THE LOCAL WATER.

The use of coagulants does not involve the employment of any particular chemical; in fact, there is quite a variety of chemicals capable of coagulating the clay in this river water, and it is possible to change from one to another without expense, or at a merely nominal cost, provided such a step seemed advisable.

Taking every thing into consideration, it is our judgment that sulphate of alumina is the most suitable coagulating chemical now on the market. It is fairly cheap (about 1.4 cents per pound), and serves to coagulate the clay in the water under proper care, with no serious detriment to the filtered water.

When sulphate of alumina is applied in the required amounts to the local water, it is decomposed by the carbonates and bicarbonates naturally present in the water. With suitable supervision and attendance for a plant, the inadmissible state of affairs of having undecomposed chemical pass into the filtered water would be entirely unnecessary and inexcusable, as is shown at length in Chapters VI to IX.

Upon the decomposition of the sulphate of alumina there is formed in the water aluminum hydrate, a white gelatinous solid, which coagulates the clay, and is subsequently removed by subsidence or by filtration.

The only changes in the filtered water are that carbonic acid is set free, and the carbonates of lime and magnesia are

converted into the form of the soluble sulphates of these bases in quantities substantially proportional to the amount of sulphate of alumina applied to the water. While these changes are undesirable, it can be positively stated that, in the quantities required for the treatment of this water, they are not injurious to health, and can not be regarded as seriously objectionable.

In the filtered water at Cincinnati, obtained with the aid of sulphate of alumina, the amount of carbonic acid would be only about one half of that naturally present in the Ohio River water at Louisville; and, while it would be somewhat of a factor in the corrosion of uncoated iron pipe, etc., there is no reason for believing that this is an important factor, practically speaking. With regard to its action on lead pipe, the filtered water would quickly form a protective coating on the pipe.

With reference to the conversion of lime and magnesia salts from carbonates to sulphates, it is very doubtful whether steam raisers could detect the change in the filtered water, as judged by incrustations in steam boilers. At times of long freshets, when the amount of applied chemical would be greatest, the total amount of incrusting constituents in the filtered water would hardly exceed the amount naturally present in the river water during low stages of the river; and at times of low and fairly clear water in the river the application of chemicals, if used, would make but little difference in the total quantity in the filtered water, from a practical standpoint.

In fact, there is considerable probability that the elimination of silt and clay would make the filtered water (obtained with the assistance of coagulation) a more desirable boiler water than the unclarified river water now in use.

TWO METHODS BY WHICH USE MAY BE MADE OF COAGULANTS.

There are two methods by which use may be made of coagulation in the clarification and purification of the local river water. They are described and discussed at length in Chapters VI to IX, inclusive. In brief, the two methods, called the modified English system and the American system, may be outlined as follows:

The Modified English System.

In this system or method a coagulant is used only at those times when economical provisions for plain subsidence are incapable of preparing the turbid river water adequately for filtration, and in such amounts that the water going upon the English filters may be properly and readily filtered. It is essential in this method that provisions be made to allow the coagulated suspended matters in the water to subside, so that they will not rapidly close up the pores of the sand layer at the surface. That is to say, the water applied to the English filters must be substantially free of coagulated masses of clay.

There were investigated two procedures for the application of the chemical when required, as follows:

1. Applying the chemical to the plain subsided water when its condition demanded it, and then allowing the coagulated portions in suspension to subside in a relatively small basin interposed between the plain subsiding reservoirs and the filters.

2. Applying the chemical to the river water, when required, before the water entered the plain subsiding reservoirs, and allowing the supplementary clarification to take place in the main subsiding reservoirs, thus dispensing with the small intermediate basin.

Each of these procedures has its advantages, but experience indicated that for economical reasons the second one would be preferable.

After getting the applied water uniformly prepared for filtration, the English type of filters can complete the clarification and purification in a satisfactory manner, and with a smaller area of filters than is conventionally considered to be necessary. For a review of the leading conditions indicated to be most practicable with regard to the construction and operation of English filters, reference is made in the latter portions of Chapters V and VII.

The American System.

With this system the chemical is uniformly applied to the water after it leaves the plain subsiding reservoirs, the amount of chemical varying with the amount of suspended matter in the water. To facilitate the operation of the plant and to lessen the total cost of the filtered water, the water should be given an intermediate subsidence after the application of the chemical. This period of coagulation and intermediate subsidence can be varied to advantage according to the turbidity of the subsided water from about 0.5 to 6 hours, as shown by the results of these investigations.

As the water reaches the filters, it must contain a certain amount of coagulant, either left from a primary application or provided by a secondary application, so that the water may be successfully filtered through American (so-called mechanical) filters at a rate from thirty to forty times as fast as in the case of English filters.

Reference is made to the last part of Chapter IX for a resumé of the best conditions as to the construction and operation of American filters.

ECONOMICAL LIMIT TO WHICH THE REMOVAL OF SUSPENDED MATTERS CAN BE CARRIED BY PLAIN SUBSIDENCE.

Taking into consideration the fact that for a portion of the year the use of coagulants is imperative, the evidence shows that *on an average* plain subsidence can not be economically carried beyond about 24 hours, when viewed from a theoretical and absolute standpoint. The reason of this is that the removal of suspended matters effected by plain subsidence beyond this period can be more economically accomplished by the use of coagulants.

However, from a practical point of view, it is necessary to consider other factors in connection with the best period to provide for plain subsidence. At times of very muddy water in the river, the removal during the second day of plain subsidence would be very considerable. This would be of value in reducing the amount of required coagulant, and in maintaining a safe margin against the passage of undecomposed chemical into the filtered water. It would also permit, by virtue of the storage capacity of the subsiding reservoirs, the stopping of the river water pumps for a day or more at a time when the river water was most difficult and expensive to purify. Further, the mixing of the water in the reservoirs of this size should eliminate in a measure the variability in the composition of the water.

During all times of very turbid water, a period of 48 hours for plain subsidence would be a marked advantage in the management of a purification plant. This is because it would allow advantage to be taken of analytical evidence as to the character of the water and the best way of treating it with chemicals in the American system; and in the modified English system it would insure the removal of coagulated

clay with moderate applications of chemical, and thus avoid clogging the filters unnecessarily on the one hand, and a needlessly large amount of chemical on the other.

Taking into consideration the evidence from these tests, it appears that it would be an advantage to provide for an average period of about 48 hours of plain subsidence. Beyond this period it would not be wise to go, except in so far as convenience and economy in construction and reasonable provisions for the future would warrant.

COMPARATIVE DIFFICULTIES IN THE MANAGEMENT OF PURIFICATION PLANTS BY THE TWO METHODS.

Owing to the great variability in the composition of the Ohio River water at Cincinnati, it is not an easy matter to manage a large plant in an economical and efficient manner, and both safety and economy demand that the management of a plant, independent of the method adopted, should be in the hands of men thoroughly familiar with this line of work.

Relative to the comparative difficulties in the management of plants of the two methods under consideration at times of muddy water, the evidence shows that the American system would be materially easier to handle. There are a number of reasons for this, among which are the following:

1. It is less difficult to adjust the proper amount of coagulating chemical to the subsided water than to the much more variable river water, as explained in Chapter VII.

2. If the amount of applied chemical should happen to be too low, there is an opportunity of correcting this promptly and satisfactorily in the American method, by a secondary application at or near the filters; whereas this procedure, if needed, is impossible in the other method, because the chemical would quickly clog the filter.

To provide an ample margin in the application of chemical in the modified English method to prevent, uniformly, the occurrence of "under-treatment" would be prohibitive, on the ground of cost alone. (For more detailed information upon this topic reference is made to Chapters VII and IX.)

3. There would be experienced more or less difficulties in scraping English filters at times during winter weather, as was actually the case with filter No. 13, due to the formation of ice and the danger of freezing the sand layer, in the case of English filters without covers; and it is not unlikely that ultimately it would be found more advantageous to cover the filters, rather than allow the cold weather to reduce the net capacity of the filters to materially less than the rated capacity.

COMPARISON OF THE QUALITATIVE EFFICIENCY OF THE TWO METHODS.

Making the necessary assumption that both plants would be well managed, the evidence shows that the bacterial efficiency of the modified English system would probably be slightly greater at times than with the other method. On the basis of annual averages, the difference would be almost inappreciable, and in each case the removal would amount to more than 99 per cent of the river water bacteria. In neither case would the filters be germ proof, although, practically speaking, they would be very nearly so, if they were well managed.

In the removal of the organic matter and clay, both methods should give perfectly satisfactory results.

COMPARISON OF THE ESTIMATED COST OF THE TWO SYSTEMS PER MILLION GALLONS OF FILTERED WATER UNDER THE LOCAL CONDITIONS.

In these comparisons, both in the modified English and the American systems, the factors of cost begin with the discharge of the river water into the subsiding reservoirs, and end with the discharge of the filtered water from a clear well into a gravity conduit leading to the city. Exclusive of the cost of the land, which is included in a tract now owned by the city, the estimates of cost of purification by the two systems cover all items of practical significance, independent of the maintenance of the grounds.

These estimates are based for convenience on a daily capacity of eighty million gallons. In some of its parts the actual purification works would be larger than this (owing to economy in providing for the future), and in other parts they would perhaps be a little smaller at the beginning.

Relative to these estimates, it is to be clearly understood that they are made for the purpose of comparison only. While they are based on the best evidence now available, and it is believed that they are substantially correct, yet for construction work they do not represent actual cost as determined from complete plans.

In the case of both systems the depreciation of the plant, independent of general repairs and the replacement of machinery, is provided for by the sinking fund.

MODIFIED ENGLISH SYSTEM.

The estimates for this system are based on the decision given in Chapter VII, that it would be more practicable to apply the chemical when needed to the river water as it

entered the reservoirs, and do away with an intermediate basin for supplementary subsidence, and at the entrance to which the chemical would be applied.

Estimated Cost of Construction per Million Gallons.

Subsiding reservoirs for 48 hours of average subsidence (96 hours of actual capacity)	$16,000 00
Pipe line from the reservoir to the filter plant, and direct connections between the force mains and the filter plant	500 00
Filter plant on the basis of $50,000 per acre, including grading, all immediate piping and appurtenances, chemical devices, laboratory and office, and at an estimated net capacity of three million gallons per acre daily	16,667 00
Clear well for filtered water (20 million gallons capacity and uncovered), with piping	1,250 00
Total	$34,417 00
Fixed charges for interest and sinking fund at 5 per cent per annum	$4 72

Estimated Cost of Operation (exclusive of Supervision and Attendance) per Million Gallons.

Scraping the surface of the sand layer 20 times per annum, at 325 man-hours per scraping per acre, with labor at 20 cents per hour	$1 19
Estimated average allowance for removing ice and increased cost of scraping during severe winter weather	30
Washing the removed sand, 1.75 cubic yards, at 40 cents	70
Replacing the washed sand, 1.75 cubic yards, at 20 cents	35
Chemical, 0 95 grain of sulphate of alumina per gallon, at 1.4 cents per pound	1 90
Total	$4 44

Estimated Cost of Supervision and Attendance per Annum for an Eighty Million Gallon Plant.

	Per Annum.
One superintendent	$4,000 00
One assistant superintendent	2,400 00
Two analysts	3,000 00
Three assistants and clerks	1,800 00
One janitor	600 00
One night watchman	720 00
Three attendants for subsiding reservoirs	2,160 00
Three gatemen for filters	2,160 00
One chemical attendant and storekeeper	720 00
Five chemical attendants for six months per annum	1,800 00
Extra labor as required, including cleaning of the reservoirs, etc.	1,500 00
Total	$20,860 00
Cost per million gallons	$0 72

Total Cost of the Modified English System per Million Gallons of Filtered Water.

Fixed charges on the cost of construction	$4 72
Operation exclusive of supervision and attendance	4 44
Supervision and attendance	72
Repairs of plant estimated at 0.5 per cent per annum	47
Total	$10 35

American System—Estimated Cost of Construction per Million Gallons.

Subsiding reservoirs for 48 hours of average subsidence (96 hours of actual capacity)	$16,000 00
Pipe line from the reservoirs to the filter plant, and direct connections between the force mains and the filter plant	500 00
Coagulating and supplementary subsiding basin (20 million gallons capacity), including piping to the filters	1,500 00
Filter plant complete, including foundations, filters, house, piping, appurtenances, chemical devices, wash-water pumps, laboratory, and office; and at an estimated actual rate of filtration of 125 million gallons per acre daily	7,500 00
Clear well for filtered water (20 million gallons capacity and uncovered), with piping	1,250 00
Total	$26,750 00
Fixed charges for interest and sinking fund at 5 per cent per annum	$3 67

Estimated Cost of Operation (exclusive of Supervision and Attendance) per Million Gallons.

Wash water, 5 per cent of filtered water at $15 per million gallons	$0 75
Coal for pumping wash water, agitating filters, heating and lighting the plant	15
Chemical, 1.6 grains of sulphate of alumina per gallon, at 1.4 cents per pound	3 20
Total	$4 10

Estimated Cost of Supervision and Attendance per Annum for an Eighty Million Gallon Plant.

	Per Annum
One superintendent	$4,000 00
One assistant superintendent	2,400 00
Two analysts	3,000 00
Three assistants and clerks	1,800 00
Three attendants for subsiding reservoirs	2,160 00
One janitor	600 00
Fifteen attendants for filters and chemical devices	10,800 00
One mechanic	1,440 00
Three engineers	4,320 00
Three firemen	2,160 00
Extra labor required, including the cleaning of reservoirs, etc.	1,500 00
Total	$34,180 00
Cost per million gallons	$1 17

Total Cost of American System per Million Gallons of Filtered Water.

Fixed charges on the cost of construction	$3 67
Operation exclusive of supervision and attendance	4 10
Supervision and attendance	1 17
Repairs and replacement of machinery and chemical devices, estimated at 10 per cent per annum on $2,500	69
Repairs of plant, exclusive of machinery and chemical devices, estimated at 0.5 per cent per annum	33
Total	$9 96

In this connection it is to be stated that consideration was given to the advisability in the American system of enlarging the coagulating basin from a capacity of 6 hours to a 12 hours flow; eliminating the plain subsiding reservoirs and the pipe

lines to and from the location of the coagulating basin to the reservoirs; and removing the cost of pumping the water to the 30 feet in elevation thus eliminated. Were it not for the very muddy condition of the river water, amounting to about two to six weeks in different years, it would clearly be cheaper and better to adopt this procedure rather than the one considered in these estimates.

As the local conditions actually exist, the cost of this procedure would not probably for any year exceed the one considered by more than 15 to 20 per cent, and during some years it would probably be a little cheaper; but it would be more difficult to operate at times of very muddy river water; the limited storage facilities would demand the treatment of the most difficult grades of river water; the amount of required chemical would be high at times of heavy freshets, reaching even 10 grains per gallon in some instances; it would be necessary to apply alkali to decompose such an amount of chemical; and the larger amounts of wash water used at such times would call for filters of greater total area.

Taking every thing into consideration, this procedure is dismissed from further attention in connection with the local problem.

Final Comparison of the Estimated Total Cost of the Two Systems under Local Conditions per Million Gallons of Filtered Water.

Modified English System, ...	Cost,	$10 35
American System, ...	"	9 96

While the above comparisons show that the modified English system would be somewhat more expensive than the American system, it is to be stated further that, owing to the topography of the ground at California, it is doubtful whether English filters having a total capacity of more than 60 million

gallons daily could be built at the rate of $50,000 per acre. In fact, for a plant materially larger than this, the cost per acre would be much in excess of the estimated cost, owing to the large amount of grading which would be required. Furthermore, the estimates ignore the open question as to the ultimate advisability of covering the filters, to prevent marked decreases in the capacity of the filters during cold weather.

If the evidence available at this time allowed these factors to be taken into consideration in definite terms, it is plainly seen that the increase in cost of the modified English system over the American system would be greater than is given above.

FINAL CONCLUSION.

The evidence obtained during these investigations shows that it is practicable to clarify and purify the Ohio River water in a satisfactory manner by either the modified English system or by the American system. Of these two systems, the experience and data indicate clearly that the American system would be the less difficult to operate; would be somewhat cheaper; would give substantially the same satisfactory quality of filtered water; and could be much more readily and cheaply enlarged for future requirement. It is therefore considered that the American system of clarification and purification would be the more advantageous to adopt for the local water supply.

Respectfully submitted,

GEORGE W. FULLER,
Chief Chemist and Bacteriologist.

CINCINNATI, O., January 31, 1899.

APPENDIX.

APPENDIX I.

ENGLISH FILTERS.

Daily Record of the Operation and Efficiency of Filter No. 1.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Bacteria per Cubic Centimeter. Effluent. 4 P M	Bacteria per Cubic Centimeter. Effluent. 12 P M	Bacteria per Cubic Centimeter. Effluent. Average.	Average Bacterial Efficiency.
March 28	11.0	1.55	....	169	....				....	....	3,500	....	3,500	....
29	11.0	1.85	....	140	40	.238	.156	34.5	16,600	2,900	....	3,200	3,000	81.9
30	10.5	2.18	0.2	115	40	5.0	3.2	36.0	11,200	5,500	3,700	2,000	3,700	66.9
31	9.0	2.45	0.2	171	40	.226	.190	15.9	5,700	1,300	1,900	2,100	1,800	68.4
April 1	9.0	2.45	0.3	86	40	4.7	4.0	14.9	9,500	2,700	1,800	1,000	1,800	81.1
2	9.5	2.57	0.3	83	35				4,700	1,800	1,200	....	1,500	68.1
3	9.5	2.51	0.3	75	30	.....	....	....	6,100	....	....	1,600	1,600	73.8
4	8.8	2.54	0.4	80	25	.166	.120	27.7	4,100	1,300	1,600	1,100	1,300	68.3
5	7.0	2.53	0.5	75	25	3.5	2.6	25.7	3,600	1,100	1,100	1,000	1,100	69.4
6	6.5	2.50	0.6	40	25				3,500	900	950	700	850	75.7
7	6.0	2.48	0.7	52	20	.165	.076	53.9	3,400	450	375	475	425	87.5
8	7.0	2.59	0.8	90	15	3.4	2.1	38.2	2,700	700	350	600	550	79.6
9	8.0	2.45	1.0	50	15				2,100	650	500	....	600	71.4
10	8.0	2.73	1.5	92	15	.....	....	....	2,800	....	....	650	650	76.8
11	8.5	2.57	2.2	61	20	.126	.076	39.7	3,800	....	190	170	180	95.3
12	8.5	2.53	2.6	71	20	2.8	1.5	46.4	1,900	250	95	110	150	92.1
13	9.0	2.65	3.3	65	15				2,200	120	250	200	190	91.4
14	8.5	2.54	3.7	86	10	.102	.058	43.2	2,400	170	120	120	140	94.2
15	9.0	2.56	3.7	39	8	2.3	1.4	39.1	2,300	110	110	190	140	93.9
16	10.0	2.60	3.9	43	6				3,500	200	190	190	190	94.6
17	13.0	2.61	4.1	34	6	.....	....	....	2,700	....	....	180	180	93.3
18	13.0	2.60	4.4	23	5	.086	.062	27.8	4,400	130	140	325	200	95.5
19	13.0	2.60	4.5	26	4	1.5	1.2	20.0	3,700	170	220	180	190	94.9
20	11.5	2.61	4.8	30	5				5,800	275	140	250	220	96.2
21	11.5	2.59	5.1	30	5	.080	.064	20.0	5,900	250	230	120	200	96.6
22	12.0	2.62	5.5	33	6	1.6	1.0	37.5	5,700	120	190	120	140	97.5
23	13.0	2.68	6.2	28	5				6,300	120	160	....	140	97.8
24	12.5	2.65	6.8	25	4	.....	....	....	6,100	....	....	140	140	97.7
25	12.0	2.62	7.7	31	3	.102	.052	49.0	7,700	130	280	100	150	98.1
26	13.0	2.34	*	27	3	2.1	1.2	42.9	5,300	90	140	90	110	97.9
27	11.5	1.76	0.2	25	3				12,200	170	400	400	325	97.3
28	12.0	2.41	0.2	17	4	.124	.068	45.2	9,600	275	130	275	230	97.6
29	12.0	2.50	0.2	28	5	2.3	1.5	34.8	6,000	325	140	160	210	96.5
30	13.0	2.60	0.2	9	6				4,100	120	170	....	150	96.3
May 1	14.0	2.34	0.3	37	5	.....	....	....	8,900	....	....	100	100	98.9
2	15.5	2.65	0.3	37	6	.136	.081	38.3	4,500	120	95	110	110	97.6
3	16.0	2.61	0.4	80	20	3.2	1.9	40.7	6,200	130	95	85	100	98.4
4	15.5	2.56	0.4	38	8				3,300	120	60	85	90	97.6
5	15.0	2.71	0.5	21	8	.118	.070	40.7	2,100	85	75	55	70	96.7
6	14.0	2.68	0.6	19	6	2.8	2.0	28.5	2,900	28	60	24	37	98.7
7	11.0	2.73	0.6	23	5				1,900	45	49	....	47	97.5
8	11.0	2.78	0.9	30	16	.....	....	....	2,700	....	....	55	55	98.0
9	12.0	2.76	1.2	24	15	.196	.088	55.1	2,300	80	140	250	160	93.0
10	13.0	2.69	1.8	129	20	3.7	2.1	43.2	15,300	600	350	250	400	97.4
11	14.0	2.65	1.6	82	16				12,200	240	250	220	240	98.0
12	14.0	2.68	1.7	68	16	.152	.082	46.1	8,000	170	85	120	120	98.5
13	14.0	2.70	1.8	52	9	3.5	2.1	40.0	4,300	90	75	230	130	97.0
14	15.0	2.74	1.9	41	8				3,100	85	75	....	80	97.4

* Closed inlet April 26, 4 P. M.; closed outlet April 27, 11 P. M. Opened inlet, after scraping, April 27, 3 P. M.; opened outlet April 27, 3:45 P. M.

Daily Record of the Operation and Efficiency of Filter No. 1.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million.		Total Organic Matter. Parts per Million.			Bacteria per Cubic Centimeter.					Average Bacterial Efficiency
					Subsided Water.	Effluent.	Subsided Water.	Effluent.	Percentage Removal.	Subsided Water.	Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	
May	15	16.0	2.55	2.0	53	8	.....	...	...	4,000	....	....	90	90	
	16	17.0	2.65	2.1	68	8	.162	.078	50.8	4,500	90	120	75	95	
	17	17.5	2.63	2.2	36	7	3.2	1.8	44.7	3,000	65	70	60	65	
	18	17.0	2.55	2.3	62	5	.116	.076	34.5	2,000	45	50	70	55	
	19	19.0	2.67	2.4	53	5	2.5	1.5	40.0	1,900	65	43	65	60	
	20	20.0	2.64	2.5	50	5				2,600	50	37	55	47	
	21	20.0	2.69	2.7	51	3				2,000	45	65	....	55	
	22	20.0	2.68	3.1	43	5				1,500	....	....	60	60	
	23	20.0	2.68	3.3	111	13	.....	....	....	2,500	40	60	70	55	
	24	20.0	2.63	3.5	136	20	.208	.110	47.1	2,100	70	75	100	80	
	25	20.0	2.56	....	95	16	3.7	2.3	37.8	2,400	100	55	90	80	
	26	20.0	0.70	*	73	15				2,200	....	....	....	....	
	27	20.0	0 78	0.1	64	15	.138	.078	43.5	2,400	....	....	140	140	
	28	22.0	2.66	0.1	50	16	3.0	2.2	26.7	1,900	100	120	....	110	
	29	22.0	2.53	0.1	82	13				2,900	....	....	210	210	
	30	22.0	2.70	0.1	62	15	.....	....	....	3,600	....	....	65	65	
	31	22.0	2.67	0.2	51	16	.152	.074	51 3	1,500	75	70	75	75	
June	1	21.0	2.69	0.2	57	13	2.8	2 0	28.6	1,200	....	42	55	45	
	2	22.0	2.63	0.2	40	13				1,100	42	49	55	48	
	3	22.0	2.59	0.3	51	8	.132	.076	42.4	1,300	42	28	38	36	
	4	22.0	2.64	0.3	41	5	2.7	2.0	25.9	800	32	29	....	30	
	5	23.0	2.62	0.3	30	6				900	....	....	30	30	
	6	23.0	2.63	0.4	38	5	.130	.078	40.0	800	33	25	24	27	
	7	23.0	2.64	0.4	45	8	2.7	1.7	37.0	700	27	22	31	27	
	8	24.0	2.64	0.5	39	5				600	44	33	21	33	
	9	24.0	2.60	0.5	27	6	.112	.074	33 9	800	19	29	21	23	
	10	25.0	2 62	0.6	16	3	2.3	1.5	34.8	700	20	19	23	21	
	11	25.0	2.62	0.6	16	3				800	26	27	....	26	
	12	25.0	2.62	0 6	15	2	.116	.064	44.8	700	....	....	33	33	
	13	26.0	2 62	0.8	14	2	2.3	1.3	43.5	600	27	17	21	22	
	14	26.0	2.61	1.1	17	2				1,000	20	39	26	28	
	15	26.0	2.66	1.1	15	2	.116	.068	41 4	800	19	16	20	18	
	16	24.0	2 68	1.1	12	2	1.7	1.1	35.4	400	27	26	55	36	
	17	24.0	2.59	0.8	10	2				200	25	14	16	18	
	18	25.0	2.61	0.8	12	1	.104	.058	44.2	250	22	32	....	27	
	19	25 0	2.72	0.8	13	1	1.8	1.1	39.0	200	....	....	50	50	
	20	25.0	2.68	0.8	12	1				100	30	22	27	26	
	21	25.0	2 67	0.9	10	1	.090	.060	33.3	150	23	14	17	18	
	22	23.0	2.64	1.1	8	1	1.5	1.1	26.8	95	28	5	14	16	
	23	23.0	2.69	1.3	8	0				110	17	21	17	18	
	24	24.0	2.57	1.7	7	1	.090	.058	35.6	190	23	33	30	29	
	25	24.0	2.58	2.6	6	2	1.7	1.2	29.5	250	16	28	....	22	
	26	24.0	2.65	4.1	45	3				4,400	....	....	19	19	
	27	25.0	1.57	†	56	5	.148	.062	58.1	2,400	41	....	....	41	
	28	25.0	0.69	0.1	67	3	2.5	1.4	44.0	1,000	....	....	90	41	
	29	25.0	2.61	0.1	45	6				1,500	48	55	75	60	
	30	25.0	2.61	0.1	57	7	.112	.070	37.5	1,700	44	36	44	41	
July	1	26.0	2.62	0 2	69	5	2 3	1.4	39.2	1,200	32	30	130	65	
	2	26 0	2 60	0 2	134	9				2,100	130	95	....	110	
	3	26 0	2.70	0.8	111	9	.182	.076	58.2	1,500	....	....	90	90	
	4	26.0	2.67	0.3	88	8	3.3	1.9	42.4	1,200	80	....	75	80	
	5	26.0	2.68	0.3	68	8				1,500	70	49	70	65	
	6	26.0	2 67	0 3	53	12	.128	.078	39 1	2,500	47	50	55	50	
	7	27 0	2.68	0.3	37	8	2.7	1.8	33.3	3,200	65	49	60	60	
	8	27.0	2.67	0.3	23	9				550	37	38	44	40	
	9	27.0	2.64	0.3	59	8	.134	.088	34.3	650	38	50	....	44	
	10	25.0	2.67	0 3	94	9	2.6	1.6	38 5	325	....	....	37	37	

* Closed inlet May 25, 4 P. M.; closed outlet May 26, 8 A. M. Opened inlet, after scraping May 27, 2:10 P. M.; opened outlet, May 27, 5:10 P. M.

† Closed inlet June 26, 12:20 A. M.; closed outlet June 27, 4:15 P. M. Opened inlet, after scraping, June 28, 1:15 P. M.; opened outlet June 28, 5:40 P. M.

Daily Record of the Operation and Efficiency of Filter No. 1.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter.. Parts per Million. Subsided Water.	Total Organic Matter.. Parts per Million. Effluent.	Total Organic Matter.. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
July 11	25.0	2.62	0.3	33	7				1,400	50	37	26	38	97.3
12	24.0	2.62	0.4	36	7	.126	.078	38.1	1,200	36	45	27	36	97.0
13	24.0	2.64	0.4	38	8	2.3	1.8	21.7	1,500	35	37	39	37	97.5
14	24.0	2.49	0.4	28	7				650	28	27	37	31	95.2
15	25.0	2.66	0.4	22	6	.108	.074	31.5	600	35	34	38	36	94.0
16	26.0	2.72	0.4	16	6	2.1	1.6	23.8	550	31	25	....	28	94.9
17	26.0	2.56	0.5	13	4				950	....	....	28	28	97.1
18	26.0	2.62	0.6	16	3	.114	.076	33.3	450	31	25	34	30	93.3
19	26.0	2.71	0.8	18	3	2.1	1.4	33.3	550	32	27	27	29	94.7
20	27.0	2.69	0.8	8	2				3,200	19	19	50	29	99.1
21	27.0	2.58	0.9	16	4	.110	.076	30.9	1,100	17	16	29	21	98.1
22	27.0	2.59	1.3	23	2	2.2	1.4	36.4	850	17	21	26	21	92.5
23	27.0	2.59	1.8	78	3				4,800	12	14	....	13	99.7
24	27.0	2.56	2.8	133	8	.188	.074	60.7	8,400	....	....	16	16	99.8
25	28.0	2.63	....	187	8	3.1	1 5	51.6	5,500	19	34	38	30	99.5
26	27 0	1.15	*	113	11				3,300	35	....	....	35	98.9
27	28.0	0.58	0.25	90	15	.168	.100	40.5	3,600	....	....	110	65	98.2
28	28.0	2.61	0.25	66	15	3.0	1.7	63.3	2,600	450	300	85	275	89.0
29	27.0	2.62	0.3	70	14				8,000	80	95	120	100	98.8
30	27.0	2.62	0.4	131	18	.176	.100	43.2	3,300	65	85	....	75	97.7
31	27.0	2.25	0.4	192	30	3.1	1.8	42.0	2,200	....	....	80	80	96.4
Aug. 1	26.0	2.61	0.6	315	30				5,400	23	130	110	90	98.3
2	26.0	2.68	0.7	185	30	.224	.090	59.8	1,100	60	65	70	65	94.1
3	26.0	2.69	0.8	76	15	3.5	1.8	48.6	3,200	55	75	75	70	97.8
4	26.0	2.62	0.8	189	20				2,300	55	95	75	75	96.7
5	26.0	2.69	0 9	140	20	.176	.084	52.3	1,600	60	65	85	70	95.6
6	25.0	2.71	1.2	91	15	3.3	2.0	39.4	1,700	50	80	....	65	96.2
7	25.0	2.65	1.6	87	16	....	....	....	2,500	....	....	80	80	96.8
8	26.0	2.59	1.6	100	18				4,100	90	100	75	90	97.8
9	25.0	2.60	1.7	113	17				4,200	90	50	70	70	98.3
10	25.0	2.25	†	176	23	.190	.068	53.7	4,400	90	60	140	95	97.8
11	25.0	0.22	....	207	....	3.2	1.6	50.0	3,800	....	....	....	....	....
12	25.0	....	....	....	....				3,600	....	....	....	....	....
13	25.0	....	....	....	....				4,800	....	....	....	....	....
14	25.0	0.94	0.1	212	30	.234	.114	51.3	6,100	....	....	4,100	4,100	32.8
15	24.0	1.54	0.2	237	30	5.0	2.6	48.0	3,200	1,100	475	500	750	76.6
16	25.0	2.20	0.1	241	30				2,300	450	300	600	450	80.4
17	25.0	2.60	3.6	199	30				3,100	350	180	300	280	91.0
18	25.0	2.74	1.8	130	18	.180	.106	41.1	1,600	275	225	300	275	82.8
19	24.0	2.65	....	100	25	4.4	2 6	41.0	1,700	300	275	160	210	85.9
20	24.0	0.69	....	143	....				5,100	....	....	....	....	....
21	25.0	....	....	....	....				4,800	....	....	....	....	....
22	25.0	....	....	....	....	.186	.116	37.7	3,800	....	....	....	....	....
23	26.0	1.58	0.3	139	16	4.1	2.5	39.0	4,800	....	190	160	170	96.5
24	25.0	2.61	0.2	113	25				3,400	210	275	250	240	92.9
25	26.0	1 19	....	80	23				1,400	120	80	....	100	92.9
26	25.0	0.26	....	75	....	.155	.102	31.2	1,000	....	....	....	....	....
27	25.5	1.17	....	57	....	3.7	2.5	32.4	1,000	....	....	....	....	....
28	21.0	....	....	....	....				1,600	....	....	....	....	....
29	24.5	....	....	....	....				1,400	....	....	....	....	....
30	25.5	....	....	....	....	.166	....	....	1,500	....	....	....	....	....
31	25.5	2.15	0.1	93	23	3.5	....	....	1,500	....	2,000	1,700	1,800	— 20.0
Sept. 1	26.0	2.68	0.1	66	20				2,300	5,800	8,800	24,000	12,900	—461.0
2	26.0	2.68	0.1	57	18				2,200	28,000	40,000	20,000	29,300	—1232.0
3	27.0	2 56	0.1	53	16	.165	.132	20.0	1,700	7,300	5,600	....	6,400	—277.0
4	28.0	2.80	0.1	38	16	3.9	3.0	23.2	3,300	....	....	2,200	2,200	33.4
5	25.0	2.61	0.1	33	16				1,500	600	....	750	650	56.6

* Closed inlet July 25, 9:30 P. M.; closed outlet July 26, 2 P. M. Opened inlet, after scraping, July 27, 1:20 P. M.; opened outlet July 27, 6:40 P. M.

† Closed inlet August 10, 10:30 A. M.; closed outlet August 10, 12 P. M.; fine sand removed, and 1 inch of mortar sand and 11 inches of fine sand added. Opened inlet August 13, 12 M.; opened outlet August 14, 9 A. M.

Daily Record of the Operation and Efficiency of Filter No. 1.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
Sept.	6	27.0	2.65	0.1	20	12	.133	.110	20.4	1,000	600	325	375	425	57.5
..	7	25.0	2 00	0.1	12	10	3.3	2.6	21.2	450	550	400	....	475	-5.5
										600	..	....	....	....	..

Shut down filter September 7, 12 P. M.

Daily Record of the Operation and Efficiency of Filter No. 2.

March	28	11.0	2.69	....	169	...				....	....	3,100	....	3,100	
..	29	11.0	2.50	....	140	50	.238	.168	29.4	16,600	2,400	....	2,900	2,600	84 1
..	30	10.5	2.68	0.1	115	45	5.0	3.7	26.0	11,200	3,100	3,600	1,600	2,800	75 0
..	31	9.0	2.61	0.1	171	50				5,700	1,300	1,300	2,000	1,500	73 7
April	1	9.0	2.62	0.1	86	45	.226	.166	26.5	9,500	1,500	1,300	1,100	1,300	86 3
..	2	9.5	2.63	0.2	83	40	4.7	3.5	25.5	4,700	2,300	2,600	....	2,400	49 0
..	3	9.5	2.61	0.2	75	35	.....	....	....	6,100	....	....	1,500	1,500	75 4
..	4	8.8	2.61	0.2	80	30				4,100	800	2,000	1,100	1,300	68 3
..	5	7.0	2.55	0.3	75	25	.166	.138	16.9	3,600	1,300	1,400	900	1,200	66 7
..	6	6.5	2.52	0.3	40	20	3.5	2.3	34.3	3,500	1,000	900	500	800	77 1
..	7	6.0	2.53	0.4	52	15				3,400	800	950	650	800	76 5
..	8	7.0	2.53	0.5	90	13	.165	.074	55.2	2,700	850	900	550	750	72 2
..	9	8.0	2.55	0.6	50	11	3.4	2.1	38.2	2,100	230	700	....	475	77 3
..	10	8.0	2.62	0.8	92	13	.....	....	....	2,800	....	....	600	600	78 5
..	11	8.5	2.62	0.9	61	15				3,800	200	100	200	170	95 5
..	12	8.5	2.60	1.1	71	20	.126	.068	46.1	1,900	150	170	160	160	91 6
..	13	9.0	2.57	1.3	65	15	2.8	1.4	50.0	2,200	120	110	200	140	93 6
..	14	8.5	2.58	1.7	86	12				2,400	150	120	95	120	95 0
..	15	9.0	2.63	1.8	39	8	.102	.062	39.3	2,300	100	170	220	160	93 0
..	16	10.0	2.64	1.8	43	6	2.3	1.3	43.4	3,500	200	150	....	170	95 1
..	17	13.0	2.60	1.9	34	5	.....	....	..	2,700	....	....	90	90	96 7
..	18	13.0	2.61	2.0	23	4				4,400	190	180	130	170	96 1
..	19	13.0	2.64	2.2	26	6	.086	.066	23.2	3,700	180	250	150	190	94 9
..	20	11.5	2.61	2.5	30	5	1.5	1.2	20.0	5,800	275	90	140	170	97 1
..	21	11.5	2.59	2.6	30	4				5,900	170	150	190	170	97 1
..	22	12.0	2.59	2.9	33	3	.080	.058	27.5	5,700	200	230	110	180	96 8
..	23	13.0	2.62	3.3	28	3	1.6	1.1	31.2	6,300	90	110	....	100	98 4
..	24	12.5	2.59	3.4	25	4	.....	....	....	6,100	....	....	130	130	97 9
..	25	12.0	2.70	3.9	31	3				7,700	95	85	170	120	98 4
..	26	13.0	2.58	4.8	27	4	.102	.060	41.2	5,300	75	170	190	140	97 4
..	27	11.5	2.64	5.5	25	5	2.1	1.4	33.3	12,200	110	240	100	150	98 5
..	28	12.0	2.60	6.5	17	6				9,600	400	190	190	250	97 4
..	29	12.0	2.49	8.6	28	5	.124	.076	38.7	6,000	180	230	160	190	96 8
..	30	13.0	1.32	*	9	4	2.3	1.4	39.1	4,100	130	170	....	150	96 3
May	1	14.0	0.27	....	37	4	.....	....	....	8,900	....	....	210	210	97 6
..	2	15.5	0.81	0.2	37	40				4,500	275	....	550	400	91 1
..	3	16.0	2.71	0.2	80	35	.136	.108	20.8	6,200	450	220	325	375	94 0
..	4	15.5	2.64	0.2	38	16	3.2	2.4	25.0	3,300	300	170	180	220	93 3
..	5	15.0	2.52	0.2	21	20				2,100	120	110	75	100	95 2
..	6	14.0	2.50	0.2	19	13	.118	.078	33.9	2,900	70	75	90	80	97 2
..	7	11.0	2.72	0.2	23	7	2.8	2.1	25.0	1,900	90	100	....	95	95 0
..	8	11.0	2.74	0.2	30	7	.....	....	....	2,700	....	....	100	100	96 3
..	9	12.0	2.71	0.2	24	7				2,300	120	450	550	375	83 7
..	10	13.0	2.74	0.2	129	30	.196	.102	48.0	15,300	700	450	450	550	96 4
..	11	14.0	2.75	0.3	82	20	3.7	2.4	35.2	12,200	350	325	210	300	97 5

* Closed inlet April 30, 8 A. M.; closed outlet April 31, 8 A. M. Opened inlet, after scraping. May 2, 7:50 P. M.; opened outlet May 2, 10:10 P. M.

Daily Record of the Operation and Efficiency of Filter No. 2.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
May	12	14.0	2.70	0.3	68	20	.152	.102	32.9	8,000	230	120	85	140	98.2
"	13	14.0	2.67	0.3	52	16	3.5	2.2	37.2	4,300	90	90	80	86	98.0
"	14	15.0	2.67	0.3	41	13				3,100	80	55	....	70	97.7
"	15	16.0	2.67	0.4	53	12	.....	....		4,000	....	....	95	95	97.6
"	16	17.0	2.65	0.4	68	9	.162	.092	43.2	4,500	100	90	70	85	98.1
"	17	17.5	2.50	0.4	36	8	3.2	2.0	37.5	3,000	55	60	50	55	98.2
"	18	17.0	2.47	0.5	62	5				2,000	39	38	65	47	97.6
"	19	19.0	2.62	0.5	53	8	.116	.086	25.9	2,600	55	60	55	55	97.9
"	20	20.0	2.64	0.6	50	5	2.5	1.5	40.0	1,900	60	60	65	60	96.8
"	21	20.0	2.67	0.7	51	5				2,000	60	60	....	60	97.0
"	22	20.0	2.65	0.8	43	12	.....	....		1,500	....	....	70	70	95.3
"	23	20.0	2.62	0.8	111	16	.208	.124	40.4	2,500	65	90	55	70	97.2
"	24	20.0	2.63	0.8	136	25	3.7	2.4	35.2	2,100	75	80	120	90	95.7
"	25	20.0	2.60	1.0	95	20				2,400	100	65	80	80	96.7
"	26	20.0	2.56	1.1	73	20				2,200	90	85	80	85	96.1
"	27	20.0	2.53	1.2	64	9	.138	.082	40.6	2,400	65	85	42	65	97.3
"	28	22.0	2.61	1.3	50	13	3.0	2.1	30.0	1,900	100	120	....	110	94.2
"	29	22.0	2.66	1.5	82	15	.....	....		2,900	....	....	....	....	....
"	30	22.0	2.71	1.6	62	15	.....	....		3,600	....	....	80	80	97.8
"	31	22.0	2.72	1.6	51	13	.152	.080	47.4	1,500	60	65	85	70	95.3
June	1	21.0	2.76	1.7	57	13	2.8	2.0	28.6	1,200	60	....	50	55	95.4
"	2	22.0	2.70	1.8	40	8				1,100	50	44	65	55	95.0
"	3	22.0	2.63	1.9	51	8	.132	.074	44.0	1,300	36	26	31	31	97.6
"	4	22.0	2.70	2.1	41	4	2.7	2.0	25.9	800	28	30	....	29	96.5
"	5	23.0	2.64	2.2	30	4				900	....	....	40	40	95.6
"	6	23.0	2.60	2.3	38	4	.130	.072	44.6	800	32	20	29	27	96.6
"	7	23.0	2.56	2.4	45	7	2.7	1.6	40.8	700	33	21	26	27	96.1
"	8	24.0	2.54	2.7	38	6				600	23	27	27	26	95.7
"	9	24.0	2.65	2.9	27	5	.112	.070	37.5	800	21	27	25	24	97.0
"	10	25.0	2.64	3.0	16	2	2.3	1.4	39.2	700	26	28	19	24	96.6
"	11	25.0	2.60	3.1	16	2				800	31	20	....	26	96.8
"	12	25.0	2.56	3.6	15	2	.116	.066	43.1	700	....	....	39	39	94.4
"	13	26.0	2.58	*	14	2	2.3	1.4	39.2	600	21	27	45	31	94.8
"	14	26.0	1.12	0.1	17	2				1,000	41	....	55	48	95.2
"	15	26.0	2.68	0.1	15	2	.116	.084	27.6	800	65	140	110	100	87.5
"	16	24.0	2.65	0.1	12	2	1.7	1.3	23.6	400	70	31	80	60	85.0
"	17	24.0	2.74	0.1	10	1				200	27	23	30	27	86.5
"	18	25.0	2.73	0.1	12	1	.104	.066	36.5	250	20	30	....	25	90.0
"	19	25.0	2.71	0.1	13	1	1.8	1.4	22.3	200	....	....	23	23	88.5
"	20	25.0	2.70	0.1	12	1				100	31	19	16	22	78.0
"	21	25.0	2.62	0.1	10	1	.090	.062	31.1	150	24	19	15	19	87.3
"	22	23.0	2.62	0.1	8	1	1.5	1.1	26.7	95	22	34	24	27	71.6
"	23	23.0	2.63	0.1	8	....				110	34	16	43	31	71.8
"	24	24.0	2.62	0.1	7	1	.090	.060	33.3	190	30	23	43	32	83.2
"	25	24.0	2.62	0.2	6	2	1.7	1.3	23.6	250	44	40	....	42	83.2
"	26	24.0	2.60	0.3	45	6				4,400	....	....	60	60	98.6
"	27	25.0	2.58	0.4	56	7	.148	.072	51.4	2,400	41	49	41	44	98.2
"	28	25.0	2.60	0.6	67	8	2.5	1.7	32.0	1,000	34	46	49	43	95.7
"	29	25.0	2.57	0.7	45	7				1,500	37	38	50	42	97.2
"	30	25.0	2.66	0.9	57	7	.112	.070	37.5	1,700	41	34	50	42	97.5
July	1	26.0	2.64	1.3	69	6	2.3	1.6	30.4	1,200	44	110	325	160	86.7
"	2	26.0	2.57	1.6	134	12				2,100	425	160	....	300	85.7
"	3	26.0	2.65	1.4	111	12	.182	.084	53.9	1,500	....	....	250	250	83.3
"	4	26.0	2.65	1.1	88	13	3.3	1.9	42.4	1,200	130	....	140	140	88.3
"	5	26.0	2.68	0.8	68	15				1,500	150	85	85	110	92.7
"	6	26.0	2.63	1.0	53	14	.128	.092	28.2	2,500	120	90	90	100	96.0
"	7	27.0	2.61	0.9	37	12	2.7	2.0	25.9	3,200	80	65	40	65	98.0

* Closed inlet June 13, 4 P. M.; closed outlet June 14, 9 A. M. Opened inlet, after scraping, June 14, 4:30 P. M.; opened outlet June 14, 8:20 P. M.

Daily Record of the Operation and Efficiency of Filter No. 2.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
July 8	27.0	2.57	*	23	11	.134	.094	29.8	550	85	49	55	65	88.2
" 9	27.0	1.47	0.1	59	....	2.6	1.8	30.8	650	....	....	175	175	73.1
" 10	25.0	2.55	0.1	94	16				325	....	....	160	160	50.8
" 11	25.0	2.56	0.1	33	13	.126	.078	38.1	1,400	90	60	60	70	95.0
" 12	24.0	2.59	0.1	36	8	2.3	1.9	17.4	1,200	95	33	46	60	95.0
" 13	24.0	2.66	0.1	38	9				1,500	55	38	50	48	96.8
" 14	24.0	2.67	0.1	28	7	.108	.074	31.5	650	37	16	37	30	95.4
" 15	25.0	2.62	0.1	22	6	2.1	1.5	28.6	600	32	35	40	36	94.0
" 16	26.0	2.71	0.1	16	6				550	50	32	....	41	92.5
" 17	26.0	2.57	0.2	13	4	.114	.074	35.1	950	....	....	37	37	96.1
" 18	26.0	2.59	0.2	16	4	2.1	1.5	28.6	450	34	22	45	34	92.4
" 19	26.0	2.62	0.2	18	3				550	37	55	31	41	92.5
" 20	27.0	2.68	0.3	8	2	.110	.074	32.7	3,200	27	21	24	24	99.2
" 21	27.0	2.68	0.3	16	4	2.2	1.4	36.4	1,100	24	30	30	28	97.5
" 22	27.0	2.62	0.3	23	3				850	31	13	29	34	96.0
" 23	27.0	2.64	0.4	78	3	.188	.076	59.6	4,800	47	26	....	36	99.2
" 24	27.0	2.59	0.6	133	15	3.1	1.6	48.4	8,400	....	....	70	70	99.2
" 25	28.0	2.60	0.6	187	17				5,500	60	55	65	60	98.9
" 26	27.0	2.60	0.7	113	18	.168	.104	38.2	3,300	55	65	50	55	98.3
" 27	28.0	2.65	0.7	90	20	3.0	2.0	33.3	3,600	55	70	75	65	98.2
" 28	28.0	2.59	0.9	66	18				2,500	75	65	95	80	96.8
" 29	27.0	2.65	1.0	70	17	.176	.102	42.1	8,000	60	85	50	65	99.2
" 30	27.0	2.64	1.3	131	19	3.1	1.8	42.0	3,300	95	95	....	95	97.1
" 31	27.0	2.62	1.5	192	30				2,200	....	....	85	85	96.1
Aug. 1	26.0	2.62	1.5	315	30	.224	.096	57.1	5,400	130	160	120	140	97.4
" 2	26.0	2.60	2.2	185	30	3.5	2.0	42.9	1,100	85	65	125	90	91.8
" 3	26.0	2.71	1.9	76	16				3,200	75	85	130	100	96.9
" 4	26.0	2.65	1.9	180	25	.176	.090	48.9	2,300	120	120	60	100	95.6
" 5	26.0	2.63	1.8	140	23	3.3	2.0	39.4	1,600	75	90	85	85	94.7
" 6	25.0	2.57	2.1	91	20				1,700	60	85	....	70	95.9
" 7	25.0	2.47	....	87	18	.....	....	....	2,500	....	....	100	100	96.0

Permanently stopped August 7, 12 P. M.

Daily Record of the Operation and Efficiency of Filter No. 3.

March 28	11.0	2.69	....	169	....	.238	.172	27.7	.....	....	3,700	....	3,700	....
" 29	11.0	2.54	....	140	120	5.0	3.8	24.0	16,600	2,300	....	5,100	3,700	77.7
" 30	10.5	2.98	0.1	115	100				11,200	2,600	2,900	2,600	2,700	75.9
" 31	9.0	2.36	0.1	171	80	.226	.178	21.2	5,700	1,700	1,700	2,400	1,900	66.7
April 1	9.0	2.63	0.1	86	60	4.7	3.8	19.2	9,500	3,400	2,200	1,100	2,200	76.8
" 2	9.5	2.65	0.2	83	40				4,700	1,700	2,300	....	2,000	57.5
" 3	9.5	2.63	0.2	75	30	.....	....	....	6,100	....	....	1,200	1,200	80.4
" 4	8.8	2.63	0.2	80	25	.166	.108	35.0	4,100	700	1,600	1,400	1,200	70.7
" 5	7.0	2.51	0.3	75	20	3.5	2.6	25.7	3,600	1,100	1,200	1,300	1,200	66.7
" 6	6.5	2.56	0.3	40	15				3,500	1,200	1,000	950	1,000	71.5
" 7	6.0	2.59	0.4	52	14	.165	.072	56.3	3,400	1,000	1,200	275	800	76.5
" 8	7.0	2.64	0.5	90	13	3.4	2.2	35.3	2,700	400	800	475	550	79.6
" 9	8.0	2.64	0.5	50	12				2,100	450	700	....	550	73.8
" 10	8.0	2.64	0.7	92	10	.....	....	....	2,800	....	....	....	....	....
" 11	8.5	2.61	0.8	61	15	.126	.090	28.7	3,800	250	120	140	170	95.5
" 12	8.5	2.59	1.1	71	20	2.8	1.6	42.8	1,900	180	140	120	150	92.1
" 13	9.0	2.57	1.2	65	18				2,200	110	110	220	150	93.2

* Closed inlet July 8, 4 P. M.; closed outlet July 9, 8:30 A. M. Opened inlet, after scraping. July 9, 11:25 A. M.; opened outlet, July 9, 5 P. M.

Daily Record of the Operation and Efficiency of Filter No. 3.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	1 P M	12 P M	Average.	Average Bacterial Efficiency.
April	14	8.5	2.59	1.4	86	20	.102	.060	41.2	2,400	140	140	90	120	95 0
	15	9.0	2.66	1.5	39	20	2.3	1.4	39.1	2,300	120	180	200	170	92.6
	16	10.0	2.63	1.5	43	18				3,500	210	140	....	180	94.9
	17	13.0	2.63	1.5	34	16				2,700	....	....	95	95	96.5
	18	13.0	2.64	1.5	23	18	.096	.062	27.8	4,400	425	190	120	240	94.5
	19	13.0	2.62	1.6	26	16	1.5	1.2	20.0	3,700	200	150	180	180	95.1
	20	11.5	2.64	1.7	30	16				5,800	96	130	275	170	97.1
	21	11.5	2.62	1.7	30	16	.080	.060	25.0	5,900	180	220	103	170	97.1
	22	12.0	2.64	1.8	33	12	1.6	1.1	21.2	5,700	70	90	140	100	98.2
	23	13.0	2.63	1.9	28	13				6,300	120	110	....	120	98.1
	24	12.5	2.63	2.0	25	13				6,100	....	....	120	120	98.0
	25	12.0	2.64	2.2	31	10	.102	.062	39.2	7,700	90	110	80	95	98.8
	26	13.0	2.60	2.7	27	12	2.1	1.5	28.6	5,300	50	425	180	220	95.9
	27	11.5	2.63	3.1	25	12				12,200	190	290	230	240	98.0
	28	12.0	2.66	3.5	17	8				9,600	260	110	150	170	98.2
	29	12.0	2.63	3.9	28	5	.124	.076	38.7	6,000	160	150	140	150	97.5
	30	13.0	2.59	4.4	9	4	2.3	1.5	34.8	1,100	70	100	....	85	97.9
May	1	14.0	2.68	4.7	37	5				8,900	....	....	120	120	98.7
	2	15.5	2.42	5.7	37	5				4,500	120	150	120	130	97.1
	3	16.0	2.60	11.4	80	18	.136	.082	39.8	6,200	120	110	120	120	98.1
	4	15.5	1.51	*	38	6	3.2	1.9	40.7	3,300	120	120	140	130	96.1
	5	14.0	0.86	0.2	21	25				2,100	....	....	90	190	90.1
	6	11.0	2.73	0.2	19	20	.118	.090	23.7	2,900	140	120	210	160	94.5
	7	11.0	2.73	0.2	23	13	2.8	2.5	10.7	1,900	170	180	....	180	90.5
	8	11.0	2.77	0.2	30	10				2,700	....	....	240	240	91.1
	9	12.0	2.73	0.2	24	8				2,300	180	800	700	550	76.1
	10	13.0	2.72	0.2	129	30	.196	.104	46.9	15,300	1,100	600	900	850	94.4
	11	14.0	2.69	0.2	82	25	3.7	2.4	35.2	12,200	750	475	325	500	95.9
	12	14.0	2.65	0.2	68	25				8,000	275	140	150	190	97.6
	13	14.0	2.66	0.2	52	18	.152	.112	26.3	4,300	160	170	95	140	96.7
	14	15.0	2.68	0.2	41	9	3.5	2.2	37.2	3,100	85	65	....	75	97.6
	15	16.0	2.67	0.2	53	10				4,000	....	....	110	110	97.2
	16	17.0	2.69	0.3	68	9				4,500	160	120	90	120	97.3
	17	17.5	2.67	0.4	36	8	.162	.086	46.9	3,000	65	95	120	95	96.8
	18	17.0	2.61	0.4	62	6	3.2	1.8	44.7	2,000	90	90	300	160	92.0
	19	19.0	2.61	0.4	53	7				2,600	100	70	70	80	96.9
	20	20.0	2.63	0.5	50	5	.116	.088	24.2	1,900	60	75	75	70	96.3
	21	20.0	2.68	0.5	51	5	2.5	1.6	36.0	2,000	44	65	....	55	97.2
	22	20.0	2.66	0.6	43	12				1,500	....	....	70	70	95.3
	23	20.0	2.63	0.6	111	20				2,500	75	95	90	85	96.6
	24	20.0	2.67	0.7	136	30	.208	.112	46.2	2,100	90	85	110	95	95.5
	25	20.0	2.67	0.8	95	30	3.7	2.4	35.2	2,400	100	95	110	100	95.8
	26	20.0	2.67	0.9	73	23				2,200	60	80	55	65	97.0
	27	20.0	2.68	1.0	64	9	.138	.020	34.8	2,400	55	60	110	75	96.9
	28	22.0	2.66	1.1	50	13	3.0	2.1	30.0	1,900	85	80	....	80	95.8
	29	22.0	2.65	1.2	82	16				2,900	....	....	90	90	96.9
	30	22.0	2.64	1.3	62	17				3,600	....	....	65	65	98.2
	31	22.0	2.62	1.3	51	18	.152	.078	48.7	1,500	60	50	60	55	96.3
June	1	....	....	....	....	16	2.8	2.1	25.0	.....	....	....	....	....	....

* Closed inlet May 4, 8 A. M.; closed outlet May 4, 12 P. M. Opened inlet, after scraping, May 5, 4:55 P. M.; opened outlet May 5, 8 P. M.

Daily Record of the Operation and Efficiency of Filter No. 4.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
March 28	11.0	3.50	....	169	....	.238	.150	37.0	.....	.....	4,600		4,600	
" 29	11.0	3.42	....	140	20	5.0	3.1	38.0	16,600	5,200	....	2,300	3,800	
" 30	10.5	4.27	0.5	115	25				11,200	3,900	3,000	3,200	3,400	
" 31	9.0	4.33	0.5	171	25	.226	.164	27.5	5,700	2,800	1,900	2,500	2,400	
April 1	9.0	4.07	0.6	86	35	4.7	3.4	27.7	9,500	2,200	1,900	1,100	1,700	
" 2	9.5	3.91	0.6	83	40				4,700	1,800	1,100	....	1,400	
" 3	9.5	3.80	0.7	75	30	.....	....	....	6,100	....	....	1,000	1,000	
" 4	9.0	3.96	0.8	80	25	.166	.116	30.2	4,100	1,300	700	1,000	1,000	
" 5	7.0	3.94	0.9	75	20	3.5	2.6	25.7	3,600	900	550	700	700	
" 6	6.5	3.91	1.1	40	15				3,500	1,100	1,200	700	1,000	
" 7	6.0	3.85	1.2	52	16	.165	.086	47.8	3,400	700	550	550	600	
" 8	7.0	3.86	1.5	90	15	3.4	2.1	38.2	2,700	600	600	550	600	
" 9	8.0	3.88	1.7	50	15				2,100	550	650	....	600	
" 10	8.0	3.86	2.4	92	15	.....	....	....	2,800	....	....	300	300	
" 11	8.5	4.08	3.3	61	15	.126	.072	42.8	3,800	275	200	180	220	
" 12	8.5	3.87	3.8	71	11	2.8	1.4	50.0	1,900	210	100	95	130	
" 13	9.0	3.78	4.9	65	12				2,200	150	120	160	140	
" 14	8.5	3.98	5.0	86	10	.102	.072	29.5	2,400	150	120	100	120	
" 15	9.0	4.03	5.1	39	8	2.3	1.3	43.4	2,300	100	140	230	160	
" 16	10.0	4.00	5.2	43	6				3,500	200	170	....	190	
" 17	13.0	4.02	5.4	34	8	.....	....	....	2,700	....	....	150	150	
" 18	13.0	4.10	6.0	23	8	.096	.056	34.8	4,400	250	140	130	170	
" 19	13.0	4.00	6.3	26	6	1.5	1.2	20.0	3,700	190	210	170	190	
" 20	11.5	4.05	7.1	30	4				5,800	190	120	150	150	
" 21	11.5	3.99	8.0	30	4	.080	.056	30.0	5,900	170	250	110	180	
" 22	12.0	3.94	9.1	33	4	1.6	1.0	37.5	5,700	100	130	130	120	
" 23	13.0	3.90	10.8	28	4				6,300	160	150	....	160	
" 24	12.5	4.01	11.2	25	4	.....	....	....	6,100	....	....	100	100	
" 25	12.0	2.63	*	31	4	.102	.050	51.0	7,700	140	80	100	110	
" 26	13.0	1.06	0.5	27	8	2.1	1.1	47.6	5,300	140	....	325	350	
" 27	11.5	4.09	0.5	25	6				12,200	425	425	500	450	
" 28	12.0	4.06	0.5	17	5	.124	.076	38.7	9,600	300	220	150	220	
" 29	12.0	4.05	0.5	28	5	2.3	1.5	34.8	6,000	190	160	150	170	
" 30	13.0	4.00	0.6	9	4				4,100	150	130	....	140	
May 1	14.0	3.98	0.7	37	4	.....	....	....	8,900	....	....	140	140	
" 2	15.5	3.86	1.0	37	3	.136	.082	39.8	4,500	110	110	110	110	
" 3	16.0	3.92	1.1	80	8	3.2	1.8	43.8	6,200	110	110	150	120	
" 4	15.5	3.99	1.2	38	7				8,300	110	180	160	150	
" 5	15.0	4.03	1.4	21	6	.118	.076	35.6	2,100	95	70	40	70	
" 6	14.0	3.94	1.6	19	5	2.8	1.8	35.7	2,900	48	65	36	50	
" 7	11.0	4.03	1.9	23	5				1,900	45	28	....	36	
" 8	11.0	4.00	2.3	30	5	.....	....	....	2,700	....	....	36	36	
" 9	12.0	3.90	2.7	24	5	.196	.084	57.2	2,300	48	90	120	85	
" 10	13.0	4.02	3.7	129	8	3.7	2.0	45.9	15,300	180	220	170	190	
" 11	14.0	3.96	†	82	9				12,200	170	180	130	160	
" 12	14.0	1.60	0.4	68	20	.152	.090	40.8	8,000	....	....	210	180	
" 13	14.0	4.20	0.4	52	20	3.5	1.9	45.7	4,300	220	250	170	210	
" 14	15.0	4.19	0.4	41	13				3,100	130	110	....	120	
" 15	16.0	4.31	0.5	53	12	.....	....	....	4,000	....	....	150	150	
" 16	17.0	4.15	0.5	68	8	.162	.080	50.6	4,500	130	170	70	120	
" 17	17.5	4.02	0.6	36	7	3.2	1.8	44.7	3,000	55	65	39	55	
" 18	17.0	4.19	0.7	62	5				2,000	50	48	90	65	
" 19	19.0	4.26	0.8	53	5	.116	.080	31.1	2,600	42	65	44	50	
" 20	20.0	4.22	0.8	50	4	2.5	1.5	40.0	1,900	44	75	60	60	
" 21	20.0	4.20	0.9	51	3				2,000	50	47	....	48	

* Closed inlet April 25, 9:40 A. M.; closed outlet April 26, 1 P. M. Opened inlet, after scraping, April 26, 6 P. M.; opened outlet, April 26, 8:30 P. M.

† Closed inlet May 11, 4:35 P. M.; closed outlet May 12, 8 A. M. Opened inlet, after scraping May 12, 3:30 P. M.; opened outlet May 12, 6:05 P. M.

Daily Record of the Operation and Efficiency of Filter No. 4.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
May	22	20.0	4.30	1.0	43	5	.....	...		1,500	...	....	42	42	97.2
	23	20.0	3.92	1.2	111	9	.208	.110	47.1	2,500	50	85	75	70	97.2
	24	20.0	4.15	1.3	136	16	3.7	2.2	40.6	2,100	55	95	100	85	96.0
	25	20.0	4.01	1.5	95	16	.138	.072	47.8	2,400	130	110	170	140	94.2
	26	20.0	4.16	1.9	73	13	3.0	1.8	40.0	2,200	106	120	100	110	95.0
	27	20.0	4.05	2.0	64	8				2,400	75	85	85	80	96.7
	28	22.0	4.04	2.3	50	8				1,900	80	90	....	85	95.5
	29	22.0	4.16	2.8	82	8	.....	....	....	2,900	....	....	100	100	96.5
	30	22.0	4.08	3.1	62	9	.....	....	....	3,600	....	....	50	50	98.6
	31	22.0	4.06	3.4	51	9	.152	.072	52.6	1,500	55	55	65	60	96.0
June	1	21.0	4.07	3.6	57	8	2.8	1.7	39.3	1,200	...	49	46	48	96.0
	2	22.0	4.03	3.8	40	8	.132	.070	47.0	1,100	42	49	55	50	95.5
	3	22.0	2.44	*	51	6	2.7	1.8	33.3	1,300	....	....	....	50	96.1
	4	22.0	3.45	0.3	41	4				800	60	44	....	50	93.8
	5	23.0	4.03	0.3	30	4	.130	.068	47.7	900	....	....	85	85	90.5
	6	23.0	4.07	0.3	38	4	2.7	1.6	40.8	800	41	32	45	39	95.1
	7	23.0	3.98	0.3	45	7				700	47	39	42	43	93.9
	8	24.0	4.03	0.3	38	6	.112	.068	39.3	600	36	27	27	30	95.0
	9	24.0	3.96	0.3	27	5	2.3	1.4	39.2	800	22	33	37	31	96.1
	10	25.0	4.18	0.4	16	2				700	50	31	22	34	95.1
	11	25.0	4.12	0.4	16	2				800	19	32	....	26	96.8
	12	25.0	4.09	0.4	15	2	.116	.064	44.8	700	...	....	60	60	91.4
	13	26.0	4.09	0.5	14	1	2.3	1.3	43.5	600	23	37	27	29	95.2
	14	26.0	4.04	0.6	17	1				1,000	16	17	34	22	97.8
	15	26.0	4.12	0.6	15	1	.116	.082	29.4	800	19	23	20	21	97.4
	16	24.0	4.04	0.6	12	1	1.7	1.2	29.5	400	17	16	18	17	95.8
	17	24.0	4.03	0.7	10	1				200	14	16	23	18	91.0
	18	25.0	4.08	0.7	12	1	.104	.060	42.3	250	13	18	....	16	93.6
	19	25.0	4.08	0.8	13	1	1.8	1.1	39.0	200	...	....	13	13	93.5
	20	25.0	4.11	0.9	12	1				100	24	15	12	17	83.0
	21	25.0	4.12	1.1	10	1	.090	.060	33.3	150	15	15	9	18	91.3
	22	23.0	3.99	1.1	8	1	1.5	1.0	33.3	95	14	22	11	16	83.2
	23	23.0	3.98	1.5	8	0				110	16	21	16	18	83.6
	24	24.0	4.03	1.9	7	1	.090	.058	35.6	190	16	20	32	23	87.9
	25	24.0	3.94	3.5	6	1	1.7	1.1	35.3	250	22	35	....	28	88.8
	26	24.0	3.22	†	45	....	.148	.066	55.4	4,400	....	....	....	....	....
	27	25.0	0.95	0.3	56	1				2,400	....	....	....	65	97.3
	28	25.0	4.00	0.3	67	2	2.5	1.3	48.0	1,000	46	22	33	34	96.6
	29	25.0	4.00	0.3	45	4				1,500	34	46	55	45	97.0
	30	25.0	4.00	0.4	57	2	.112	.064	42.9	1,700	27	19	27	24	98.6
July	1	26.0	4.01	0.4	69	3	2.3	1.2	47.9	1,200	35	23	41	33	97.2
	2	26.0	3.82	0.5	134	6				2,100	49	49	49	49	97.7
	3	26.0	4.00	0.5	111	5	.182	.074	59.3	1,500	....	....	60	60	96.0
	4	26.0	3.97	0.5	88	4	3.3	1.7	48.5	1,200	28	....	65	46	96.2
	5	26.0	4.02	0.5	68	6				1,500	44	37	42	41	97.3
	6	26.0	4.05	0.5	53	7	.128	.084	34.4	2,500	43	39	38	40	98.4
	7	27.0	4.07	0.5	37	6	2.7	1.7	37.0	3,200	39	39	35	38	98.8
	8	27.0	4.07	0.5	23	6				550	32	24	36	31	94.4
	9	27.0	3.99	0.6	59	6	.134	.090	32.8	650	31	30	....	30	95.4
	10	25.0	3.80	0.6	94	7	2.6	1.6	38.5	325	...	....	21	21	93.5
	11	25.0	3.99	0.7	33	7				1,400	26	32	26	28	98.0
	12	24.0	3.94	0.7	36	5	.126	.072	42.9	1,200	20	20	19	20	98.3
	13	24.0	4.01	0.8	38	6	2.3	1.5	34.8	1,500	36	22	21	26	98.3
	14	24.0	4.14	0.8	28	5				650	41	17	11	23	96.5
	15	25.0	3.97	0.8	22	4	.108	.070	35.2	600	24	27	17	23	96.2
	16	26.0	3.92	0.8	16	5	2.1	1.4	33.3	550	24	26	....	25	95.5

* Closed inlet June 3, 3:40 A. M.; closed outlet June 3, 11 A. M. Opened inlet, after scraping, June 3, 10:50 P. M.; opened outlet June 4, 3:30 A. M.

† Scraped.

Daily Record of the Operation and Efficiency of Filter No. 4.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
July	17	26.0	3.86	0.9	13	3	.114	.070	38.6	950	....	....	15	15	98 4
"	18	26.0	3.97	1.2	16	3	2.1	1.3	38.1	450	36	18	32	29	93 6
"	19	26.0	4.02	1.6	18	2				550	35	24	16	25	95 5
"	20	27.0	4.04	1.8	8	2	.110	.064	41.8	3,200	15	22	47	28	99 1
"	21	27.0	3.93	2.5	16	2	2.2	1.3	41.0	1,100	24	25	10	20	98 2
"	22	27.0	3.93	3.5	23	2				850	20	13	16	16	98 1
"	23	27.0	3.22	*	78	2				4,800	18	17	....	18	99 6
"	24	27.0	0.66	0.2	133	8	.188	.069	63.8	8,400	....	....	110	110	98 8
"	25	28.0	4.12	0.3	187	8	3.1	1.5	51.6	5,500	105	130	150	130	97 7
"	26	27.0	4.11	0.3	113	15				3,300	90	65	49	70	97 9
"	27	28.0	4.07	0.3	90	14	.168	.094	44.1	3,600	55	46	32	44	98 8
"	28	28.0	4.11	0.4	66	12	3.0	1.6	46.7	2,500	80	45	37	55	97 8
"	29	27.0	4.17	0.4	70	13				8,000	33	65	40	46	99 4
"	30	27.0	4.02	0.5	131	14	.176	.090	48 9	3,300	55	36	....	45	98 6
"	31	27.0	4.01	0.6	192	30	3.1	1.5	51.6	2,200	....	....	55	55	97 5
Aug.	1	26.0	4.04	0.7	315	30				5,400	55	80	75	70	98 7
"	2	26.0	4.01	0.7	185	23	.224	.084	62.5	1,100	37	33	75	48	95 6
"	3	26.0	4.04	0.7	76	15	3.5	1.6	54.3	3,200	46	50	70	55	98 3
"	4	26.0	3.84	0.7	189	19				2,300	65	65	110	80	96 5
"	5	26.0	4.12	0.6	140	20	.176	.080	54.6	1,600	55	32	75	55	96 6
"	6	25.0	3.99	0.5	91	13	3.3	1.7	48.5	1,700	60	50	....	55	96 8
"	7	25.0	4.00	0.5	87	14	.....	....	....	2,500	....	....	65	65	97 4
"	8	26.0	3.21	†	100	15				4,100	55	100	....	75	98 2
"	9	25.0	....	....	....	....				4,200	....	....	....	....	....
"	10	25.0	2.51	0.6	176	....	.190	.090	52.6	4,400	....	70	650	500	98 6
"	11	25.0	3.17	0.4	207	23	3.2	1.6	50.0	3,800	90	70	80	80	97 9
"	12	25.0	2.72	0.4	266	30				3,600	75	40	70	60	98 3
"	13	25.0	3.29	0.6	280	25				4,800	75	55	....	60	98 8
"	14	25.0	2.93	‡	212	30	.234	.110	53.0	6,100	....	....	85	85	98 6
"	15	24.0	0.49	....	237	....	5.0	2.3	54.0	3,200	....	....	....	....	....
"	16	25.0	1.58	0.55	241	30				2,300	....	65	120	90	96 1
"	17	25.0	2.57	0.5	199	30				3,100	100	120	120	110	96 4
"	18	25.0	3.31	0.7	130	30	.180	.114	36.7	1,600	140	110	90	110	93 1
"	19	24.0	3.93	0.8	100	25	4.4	2.9	34.1	1,700	120	55	250	140	91 8
"	20	24.0	3.99	1.0	143	25				5,100	75	50	....	60	98 8
"	21	25.0	3.91	1.2	136	16				4,800	....	....	60	60	98 8
"	22	25.0	4.06	1.4	137	18	.186	.108	42.0	3,800	36	50	40	42	98 9
"	23	26.0	4.01	1.5	139	20	4.1	2.2	46.4	4,800	40	75	55	55	98 9
"	24	25.0	4.01	1.8	113	17				3,400	65	55	80	65	98 4
"	25	26.0	3.98	2.0	80	18				1,400	46	49	40	45	96 8
"	26	25.0	2.00	....	75	20	.155	.104	33.0	1,000	25	....	....	25	97 5
"	27	25.5	....	....	....	14	3.7	2.1	43.3	1,000	....	....	....	....	....
"	28	24.0	0.64	0 7	55	....				1,600	....	....	55	55	96 6
"	29	24.5	3.06	0.8	84	11				1,400	50	35	42	42	97 0
"	30	25.5	3.97	0.9	115	18	.166	.090	45.9	1,500	65	55	48	55	96 3
"	31	25.5	4.01	0.9	93	18	3 5	2.1	40 1	1,500	65	55	65	60	96 0
Sept.	1	26.0	4.17	1.1	66	11				2,300	55	44	120	73	96 8
"	2	26.0	4.04	1.2	57	11				2,200	32	55	39	42	98 1
"	3	27.0	4.04	1.4	53	12	.165	.112	32.2	1,700	44	27	....	36	97 9
"	4	28.0	4.00	1.5	38	11	3 9.	2.3	41.1	3,300	....	....	42	42	98 7
"	5	25.0	3.99	1.6	33	10				1,500	27	....	25	26	98 3
"	6	27.0	4.03	1.7	20	9				1,000	29	26	28	27	97 3
"	7	25.0	3.65	....	12	8	.138	.100	27.6	450	19	16	32	22	95 1
"	8	23.0	0.72	....	10	....	3.3	2.2	33.4	600	....	....	....	....	....
"	9	23.0	0.89	0.7	9	....				850	....	....	12	12	98 6

* Closed inlet July 23, 8:30 A. M.; closed outlet July 23, 12 P. M. Opened inlet, after scraping, July 24, 3 P. M.; opened outlet, July 21, 8 P. M.

† Closed inlet August 8, 8:30 A. M.; closed outlet August 8, 9:35 P. M. Opened inlet, after scraping, August 9, 3:25 P. M.; opened outlet August 10, 9 A. M.

‡ Closed inlet August 14, 9 A. M.; closed outlet August 15, 3:30 A. M. Opened inlet, after scraping, August 15, 5:35 P. M.; opened outlet August 16, 9 A. M.

Daily Record of the Operation and Efficiency of Filter No. 4.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Bacteria per Cubic Centimeter. Effluent. 4 P M	Bacteria per Cubic Centimeter. Effluent. 12 P M	Bacteria per Cubic Centimeter. Effluent. Average.	Average Bacterial Efficiency.
Sept. 10	22.0	2.62	0.8	14	5				1,500	15	17	....	16	98.9
" 11	22.0	2.62	0.9	12	6	.130	.062	37.0	1,600	....	....	27	27	98.3
" 12	21.0	3.51	1.4	7	5	2.8	1.8	35.7	550	21	8	11	13	97.6
" 13	21.0	4.09	1.4	14	6				220	8	9	9	9	95.9
" 14	21.0	4.04	1.6	10	5				275	15	19	18	17	93.8
" 15	22.0	3.96	1.8	12	5	.118	.076	35.6	2,600	17	5	17	13	99.5
" 16	22.0	4.00	2.0	11	6	2.0	1.4	30.0	2,100	21	17	15	18	99.1
" 17	21.0	3.99	2.2	12	2				1,400	24	17	....	20	98.6
" 18	22.0	3.97	2.4	18	3				4,200	....	....	28	28	99.3
" 19	22.0	4.01	2.4	33	3	.114	.070	38.6	2,200	22	34	38	31	98.6
" 20	21.0	4.00	2.9	11	1	2.2	1.5	31.8	1,900	32	38	20	30	98.4
" 21	22.0	4.02	3.3	10	1				1,400	13	19	24	19	98.6
" 22	23.0	3.97	3.7	16	2	.122	.068	44.3	1,200	25	18	14	19	98.4
						2.1	1.4	33.3	5,000	17	....	....	17	99.7

Permanently stopped September 23, 9:10 A. M.

Daily Record of the Operation and Efficiency of Filter No. 5.

March 28	11.0	4.17	....	169	....	.238	.164	31.1	....	....	3,800	....	3,800	....
" 29	11.0	3.57	....	140	....	5.0	3.5	30.0	16,600	1,600	....	4,400	3,000	81.9
" 30	10.5	3.91	0.3	115	50				11,200	2,600	2,500	2,300	2,500	77.7
" 31	9.0	3.71	0.3	171	50				5,700	1,900	1,800	2,000	1,900	66.7
April 1	9.0	3.99	0.3	86	45	.226	.162	28.4	9,500	2,000	2,500	1,400	2,000	78.9
" 2	9.5	3.97	0.4	83	40	4.7	3.6	23.5	4,700	2,200	1,200	....	1,700	63.8
" 3	9.5	3.93	0.4	75	35				6,100	....	....	1,600	1,600	73.8
" 4	9.5	3.92	0.5	80	30				4,100	900	2,200	1,300	1,500	63.4
" 5	7.0	3.89	0.6	75	25	.166	.122	26.5	3,600	1,300	1,200	1,100	1,200	66.7
" 6	6.5	3.87	0.7	40	20	3.5	2.3	34.3	3,500	1,200	1,400	1,100	1,200	65.7
" 7	6.0	3.86	0.7	52	15				3,400	800	900	700	800	76.5
" 8	7.0	3.81	0.9	90	15	.165	.070	57.6	2,700	700	850	700	750	72.2
" 9	8.0	4.06	1.1	50	15	3.4	1.9	44.2	2,100	950	850	....	900	57.2
" 10	8.0	4.18	1.5	92	16				2,800	....	....	350	350	87.5
" 11	8.5	4.12	1.7	61	18	....	....	....	3,800	140	350	160	220	94.2
" 12	8.5	4.07	2.0	71	20	.126	.076	39.7	1,900	230	150	100	160	91.6
" 13	9.0	4.00	2.3	65	18	2.8	1.3	53.6	2,200	130	110	200	150	93.2
" 14	8.5	3.96	2.5	86	12				2,400	180	210	130	180	92.5
" 15	9.0	3.93	2.6	39	8	.102	.060	41.2	2,300	160	95	220	160	93.0
" 16	10.0	3.96	2.7	43	6	2.3	1.2	47.8	3,500	200	180	....	190	94.6
" 17	13.0	3.98	2.7	34	6	....	....	....	2,700	....	....	210	210	92.2
" 18	13.0	3.96	2.8	23	5	....	....	....	4,400	300	275	275	275	93.8
" 19	13.0	3.96	3.1	26	3	.086	.060	30.2	3,700	110	190	230	180	95.1
" 20	11.5	4.03	3.3	30	4	1.5	1.1	26.7	5,800	170	200	275	220	96.2
" 21	11.5	4.01	3.5	30	4	.080	.054	32.5	5,900	180	180	140	170	97.1
" 22	12.0	4.11	3.6	33	5	1.6	1.1	31.2	5,700	140	150	120	140	97.5
" 23	13.0	4.06	3.8	28	8				6,300	75	120	....	100	98.4
" 24	12.5	4.03	4.0	25	4	....	....	....	6,100	....	....	110	110	98.2
" 25	12.0	4.05	4.5	31	5	.102	.050	51.0	7,700	120	140	180	150	98.0
" 26	13.0	4.13	5.3	27	4	2.1	1.1	47.6	5,300	65	150	160	120	97.7
" 27	11.5	4.12	5.9	25	4				12,200	120	300	110	190	98.4
" 28	12.0	4.03	6.6	17	3	.124	.068	45.2	9,600	220	120	120	150	98.4
" 29	12.0	3.94	8.5	28	3	2.3	1.4	39.1	6,000	180	160	170	170	97.2
" 30	13.0	3.98	*	9	4				4,100	140	200	....	170	95.9

* Closed inlet April 30, 8 A. M ; closed outlet May 2, 10:30 A. M. Opened inlet, after scraping, May 2, 6:20 P. M.; opened outlet May 2, 9:40 P. M.

Daily Record of the Operation and Efficiency of Filter No. 5.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
May	1	14.0	2.36	....	37	3	.....	...	....	8,900	....	....	250	250	
	2	15.5	1.05	0.2	37	25	.136	.098	28.0	4,500	275	...	450	350	
	3	16.0	4.20	0.3	80	25	3.2	2.2	31 3	6,200	475	160	240	300	
	4	15.5	4.22	0.3	38	9	.118	.070	40.8	3,300	210	lost	130	170	
	5	15.0	4.19	0.4	21	8	2.8	1.9	32.1	2,100	100	77	85	90	
	6	14.0	4.18	0.4	19	9				2,900	65	75	70	70	
	7	11.0	4.13	0.5	23	6				1,900	80	80	...	80	
	8	11.0	4 13	0.5	30	5	.....	....	....	2,700	....	....	85	85	
	9	12.0	4.05	0.6	24	5	.196	.080	59.2	2,300	80	160	240	160	
	10	13.0	4.08	0.7	129	20	3.7	2 0	45.9	15,300	270	200	170	210	
	11	14.0	4.08	0.7	82	13				12,200	240	180	160	190	
	12	14.0	3.64	0.8	68	18	.152	.092	39.5	8,000	160	85	120	120	
	13	14.0	3.91	0.8	52	16	3.5	1.9	45.7	4,300	80	120	100	100	
	14	15.0	4.08	0.9	41	9				3,100	120	60	...	90	
	15	16.0	4.01	1.0	53	9	.....	....	....	4,000	....	....	95	95	
	16	17.0	4.10	1.2	68	8	.162	.080	50.6	4,500	95	60	65	70	
	17	17.5	4.10	1.4	36	7	3.2	1.6	50.0	3,000	44	33	55	44	
	18	17.0	4.06	1.5	62	4				2,000	23	26	120	55	
	19	19.0	4.20	1.6	53	4	.116	.082	29.4	2,600	75	85	60	75	
	20	20.0	4.24	1.7	50	4	2.5	1.4	44.0	1,900	75	60	65	65	
	21	20.0	4.18	1.8	51	3				2,000	43	44	...	44	
	22	20.0	4.09	2.0	43	6	.....	....	....	1,500	....	....	49	49	
	23	20.0	3.99	2.2	111	8	.208	.110	47.1	2,500	48	43	50	47	
	24	20.0	4.01	2.3	136	18	3.7	2.2	40.6	2,100	85	65	95	80	
	25	20.0	4.11	2.6	95	16				2,400	100	100	70	90	
	26	20.0	4.11	2.9	73	13	.138	.076	44.9	2,200	50	85	100	80	
	27	20.0	4.04	3.0	64	8	3.0	1.8	40.0	2,400	80	65	60	70	
	28	22.0	4.01	3.0	50	8				1,900	60	70	...	65	
	29	22.0	3.98	3.1	82	10	.....	....	....	2,900	....	....	70	70	
	30	22.0	3.98	3.2	62	11	.....	....	....	3,600	....	....	80	80	
	31	22.0	4.02	3.3	51	13	.152	.072	52.6	1,500	60	45	100	70	
June	1	21.0	4.00	3.3	57	8	2.8	1.9	32.1	1,200	70	....	100	85	
	2	22.0	4.10	3.4	40	8				1,100	55	55	95	70	
	3	22.0	3.83	3.5	51	8	.132	.072	45.5	1,300	55	48	38	47	
	4	22.0	4.02	3.7	41	6	2.7	1.8	33.3	800	34	43	...	38	
	5	23.0	4.07	3.9	80	3				900	....	....	41	41	
	6	23.0	2.71	*	38	3	.130	.068	47.7	800	37	40	...	38	
	7	23.0	1.32	0.2	45	5	2.7	1.7	37.0	700	....	67	52	60	
	8	24.0	3.98	0.2	38	5				600	47	80	220	120	
	9	24.0	4.11	0.2	27	5	.112	.068	39.3	800	120	150	210	160	
	10	25.0	4.24	0.2	16	2	2.3	1.5	34.8	700	95	110	180	130	
	11	25.0	4.06	0.3	16	2				800	120	20	...	70	
	12	25.0	3.97	0.3	15	2	.116	.064	44.8	700	....	....	60	60	
	13	26.0	3.97	0.3	14	2	2.3	1.4	39.2	600	35	38	50	41	
	14	26.0	4.13	0.4	17	1				1,000	36	37	33	35	
	15	26.0	4.07	0.4	15	1	.116	.084	27.6	800	25	21	24	23	
	16	24.0	4.07	0.5	12	1	1.7	1.2	29.5	400	15	28	26	23	
	17	24.0	4.02	0 5	10	1				200	35	24	12	24	
	18	25 0	4.05	0.6	12	1	.104	.062	40.4	250	22	11	...	16	
	19	25.0	4 18	0.6	13	1	1.8	1.1	39.0	200	....	....	22	22	
	20	25.0	4.11	0.6	12	1				100	16	10	10	12	
	21	25 0	4.07	0 6	10	0	.090	.058	35.5	150	14	18	26	19	
	22	23.0	4 01	0.6	8	0	1.5	0.9	40.0	95	15	18	18	17	
	23	23.0	4.01	0.7	8	0				110	65	16	26	35	
	24	24.0	3.98	0.8	7	1	.090	.060	33.3	190	14	23	32	23	
	25	24.0	3.94	1 3	6	1	1.7	1.1	35.3	250	24	28	...	26	
	26	24.0	4.05	1.8	45	2				4,400	....	....	45	45	
	27	25.0	3.65	2.2	56	2	.148	.066	55.4	2,400	29	21	45	32	
	28	25.0	4.00	3.0	67	1	2.5	1.4	44.0	1,000	20	35	24	26	

* Closed inlet June 6, 8 A. M.; closed outlet June 6, 5 P. M. Opened inlet, after scraping June 7, 12 M; opened outlet June 7, 4:10 P. M.

Daily Record of the Operation and Efficiency of Filter No. 5.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million.		Total Organic Matter. Parts per Million.			Bacteria per Cubic Centimeter.					Average Bacterial Efficiency.
					Subsided Water.	Effluent.	Subsided Water.	Effluent.	Percentage Removal.	Subsided Water.	Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	
June	29	25.5	3.96	3.3	45	4	.112	.064	42.9	1,500	21	28	27	25	98.3
	30	25.0	4.06	3.8	57	2	2.3	1.3	43.5	1,700	25	13	29	22	98.7
July	1	26.0	3.86	*	69	3				1,200	20	32	37	30	97.5
	2	26.0	1.75	0.2	134	....	.182	.084	53.9	2,100	....	65	....	65	96.9
	3	26.0	4.00	0.2	111	7	3.3	1.7	48.5	1,500	....	....	60	60	96.0
	4	26.0	3.93	0.2	88	9				1,200	85	....	75	80	93.3
	5	26.0	4.01	0.2	68	10	.128	.086	32.9	1,500	90	85	80	85	94.3
	6	26.0	4.08	0.3	53	13	2.7	1.7	37.0	2,500	80	50	55	60	97.6
	7	27.0	4.08	0.3	87	8				3,200	65	28	40	44	98.6
	8	27.0	4.11	0.3	23	6				550	55	50	90	65	88.2
	9	27.0	4.06	0.4	59	7	.134	.082	38.8	650	65	80	....	70	89.2
	10	25.0	4.09	0.4	94	7	2.6	1.7	34.6	325	....	....	70	70	78.5
	11	25.0	4.06	0.4	33	7				1,400	50	39	24	38	97.3
	12	24.0	4.05	0.4	36	6	.126	.072	42.9	1,200	40	37	28	35	97.1
	13	24.0	4.07	0.4	38	6	2.3	1.6	30.4	1,500	28	24	46	33	97.8
	14	24.0	4.06	0.4	28	5				650	19	41	36	32	95.1
	15	25.0	4.04	0.4	22	5	.108	.072	35.2	600	29	38	41	36	94.0
	16	26.0	4.09	0.5	16	5	2.1	1.4	33.4	550	49	80	....	65	88.4
	17	26.0	3.91	0.6	13	3				950	....	....	34	34	96.4
	18	26.0	4.03	0.6	16	3	.114	.074	35.1	450	33	65	36	45	90.0
	19	26.0	4.14	0.7	18	3	2.1	1.4	33.3	550	37	40	38	38	93.1
	20	27.0	4.15	0.8	8	2				3,200	55	36	90	60	98.1
	21	27.0	4.09	0.8	16	3	.110	.064	41.8	1,100	35	32	43	37	96.6
	22	27.0	4.09	0.9	23	2	2.2	1.3	41.0	850	27	35	55	39	95.4
	23	27.0	4.03	1.3	78	3				4,800	55	36	....	46	99.0
	24	27.0	3.73	1.6	133	7	.188	.070	62.8	8,400	....	....	46	46	99.5
	25	28.0	4.02	1.6	187	7	3.1	1.5	51.6	5,500	65	30	36	44	99.2
	26	27.0	4.02	1.6	113	11				3,300	18	46	39	34	99.0
	27	28.0	4.04	1.5	90	12	.168	.092	45.3	3,600	46	52	60	55	98.5
	28	28.0	4.04	1.5	66	11	3.0	1.5	50.0	2,500	37	35	47	40	98.4
	29	27.0	4.02	1.4	70	12				8,000	55	48	70	60	99.2
	30	27.0	4.05	1.6	131	14	.176	.088	50.0	3,300	55	50	....	50	98.5
	31	27.0	4.06	1.4	192	30	3.1	1.6	48.4	2,200	....	....	55	55	97.5
Aug.	1	26.0	4.11	1.3	315	30				5,400	80	48	75	70	98.7
	2	26.0	4.04	1.8	185	23	.224	.084	62.5	1,100	42	55	55	50	95.5
	3	26.0	4.00	†	76	15	3.5	1.6	54.3	3,200	40	49	50	46	98.6
	4	26.0	0.98	....	189	....				2,300	....	....	....	....	....
	5	26.0	2.60	0.4	140	....	.176	.068	50.0	1,600	....	70	120	85	94.7
	6	25.0	4.06	0.4	91	23	3.3	1.9	42.4	1,700	110	110	....	110	93.5
	7	25.0	4.08	0.4	87	20	.....	....	....	2,500	....	....	100	100	96.0
	8	26.0	3.98	0.4	100	20				4,100	140	100	100	110	97.3
	9	25.0	4.00	0.5	113	20				4,200	120	68	130	110	97.4
	10	25.0	4.07	0.5	176	25	.190	.088	53.7	4,400	85	60	60	70	98.4
	11	25.0	3.49	....	207	25	3.2	1.6	50.0	3,800	55	65	....	60	98.4
	12	25.0	....	....	....	....				3,600	....	....	....	....	....
	13	25.0	1.66	0.3	280	....				4,800	....	130	....	130	97.3
	14	25.0	2.57	0.3	212	30	.234	.120	48.7	6,100	....	....	200	200	96.7
	15	24.0	2.59	0.3	237	30	5.0	2.6	48.0	3,200	170	110	170	150	95.3
	16	25.0	3.53	0.5	241	20				2,300	110	180	700	325	85.9
	17	25.0	4.02	0.7	199	30				3,100	170	160	170	170	94.5
	18	25.0	4.11	0.7	130	30	.180	.118	34.4	1,600	130	200	120	150	90.6
	19	24.0	4.04	0.7	100	25	4.4	2.8	36.4	1,700	90	85	80	85	95.0
	20	24.0	3.99	0.9	143	25				5,100	110	37	....	75	98.5
	21	25.0	4.01	1.0	136	16				4,800	....	....	65	65	98.6
	22	25.0	4.09	1.1	137	20	.186	.118	36.6	3,800	80	70	75	75	98.0
	23	26.0	3.19	....	139	20	4.1	2.4	41.5	4,800	60	70	....	65	98.6

Permanently stopped August 23, 12 P. M.

* Closed inlet July 1, 3:30 P. M.; closed outlet July 2, 8 A. M. Opened inlet, after scraping, July 2, 11:30 A. M.; opened outlet July 2, 3:30 P. M.

† Closed inlet August 11, 9:50 A. M.; closed outlet August 11, 9:45 P. M. Opened inlet, after scraping, August 12, 2:25 P. M.; opened outlet August 13, 9 A. M.

Daily Record of the Operation and Efficiency of Filter No. 6.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
March 28	11.0	3.96	...	169	....	.238	.166	30.3	.....		1,000	....	1,000	
" 29	11.0	3.88	....	140	....	5.0	3.8	24.0	16,600	5,400	....	2,900	4,200	
" 30	10.5	4.28	0.2	115	70	.226	.174	23.0	11,200	2,600	3,300	2,100	2,700	
" 31	9.0	4.30	0.2	171	60	4.7	3.4	27.7	5,700	1,000	1,100	1,800	1,300	
April 1	9.0	3.93	0.2	86	50				9,500	2,800	1,700	1,700	2,100	
" 2	9.5	4.23	0.2	83	40				4,700	2,600	2,400	....	2,500	
" 3	9.5	3.59	0.3	75	30	.....	....	....	6,100	....	....	1,600	1,600	
" 4	9.0	3.86	0.3	80	25	.166	.126	24.1	4,100	500	950	1,000	800	
" 5	7.0	3.84	0.4	75	20	3.5	2.5	28.6	3,600	800	900	700	800	
" 6	6.5	3.84	0.5	40	20				3,500	1,100	1,300	425	950	
" 7	6.0	3.83	0.6	52	20	.165	.084	49.1	3,400	550	550	475	500	
" 8	7.0	3.74	0.7	90	20	3.4	2.1	38.2	2,700	550	550	350	475	
" 9	8.0	3.78	0.9	50	18				2,100	300	400	....	350	
" 10	8.0	3.91	1.2	92	16	.....	....	....	2,800	....	....	275	275	
" 11	8.5	3.86	1.4	61	18	.126	.080	36.6	3,800	170	110	100	130	
" 12	8.5	3.82	1.6	71	16	2.8	1.4	50.0	1,900	120	130	170	140	
" 13	9.0	3.85	2.0	65	18				2,200	120	100	120	110	
" 14	8.5	4.03	2.1	86	20	.102	.062	39.3	2,400	100	160	120	130	
" 15	9.0	4.00	2.3	39	22	2.3	1.3	43.4	2,300	120	170	200	160	
" 16	10.0	3.98	2.3	43	16				3,500	170	120	....	140	
" 17	13.0	3.96	2.4	34	12	.....	....	....	2,700	....	....	120	120	
" 18	13.0	4.03	2.5	23	10	.086	.054	37.2	4,400	140	275	160	190	
" 19	13.0	4.05	2.7	26	6	1.5	1.2	20.0	3,700	300	170	160	210	
" 20	11.5	4.02	2.9	30	4				5,800	150	75	220	150	
" 21	11.5	3.98	3.0	30	5	.080	.056	30.0	5,900	275	225	160	220	
" 22	12.0	4.04	3.3	33	3	1.6	1.1	31.2	5,700	80	110	140	110	
" 23	13.0	4.08	3.5	28	5				6,300	100	110	....	100	
" 24	12.5	4.05	3.6	25	5	.....	....	....	6,100	....	....	70	70	
" 25	12.0	4.01	3.9	31	5	.102	.058	43.1	7,700	130	90	110	110	
" 26	13.0	4.00	4.8	27	6	2.1	1.3	38.1	5,300	90	90	120	100	
" 27	11.5	3.75	5.2	25	5				12,200	130	150	130	140	
" 28	12.0	4.24	5.9	17	4	.124	.064	48.4	9,600	140	160	95	130	
" 29	12.0	3.96	7.0	28	5	2.3	1.3	43 5	6,000	170	90	95	120	
" 30	13.0	3.93	8.8	9	4				4,100	130	120	....	120	
May 1	14.0	3.94	11.2	37	5	.....	....	....	8,900	....	....	140	140	
" 2	15.5	2.94	*	37	5	.136	.078	42.7	4,500	110	230	325	220	
" 3	16.0	0.96	0.3	80	20	3.2	1.9	40.7	6,200	....	....	190	225	
" 4	15.5	4.03	0.3	38	16				3,300	170	210	120	170	
" 5	15.0	4.02	0.3	21	16	.118	.080	32.3	2,100	100	90	80	90	
" 6	14.0	4.00	0.3	19	9	2.8	2 1	25.0	2,900	110	80	55	80	
" 7	11.0	4.08	0.3	23	9				1,900	140	100	....	120	
" 8	11 0	4.04	0.3	30	8	.....	....	....	2,700	....	....	90	90	
" 9	12.0	3.97	0.4	24	7	.196	.088	55.1	2,300	70	190	210	160	
" 10	13.0	3.99	0.5	129	30	3.7	2.2	40.5	15,300	650	375	160	400	
" 11	14.0	3.99	0.5	82	18				12,200	140	200	110	150	
" 12	14.0	3.95	0.6	68	18	.152	.098	35.6	8,000	130	110	70	100	
" 13	14.0	3.95	0.6	52	12	3.5	2.0	42.8	4,300	75	65	65	70	
" 14	15.0	3.96	0.6	41	10				3,100	60	50	....	55	
" 15	16.0	4.02	0.7	53	8	.....	....	....	4,000	....	....	80	80	
" 16	17.0	3.99	0.9	68	8	.162	.082	49.5	4,500	110	60	65	80	
" 17	17.5	3.96	1.1	36	6	3.2	1.7	46.8	3,000	65	75	55	65	
" 18	17.0	3.98	1.2	62	5				2,000	46	44	50	47	
" 19	19.0	4.00	1.3	53	6	.116	.082	29.4	2,600	65	60	75	65	
" 20	20.0	4.05	1.3	50	5	2.5	1.6	36.0	1,900	65	55	65	60	
" 21	20.0	4.04	1.4	51	4				2,000	46	38	....	42	
" 22	20.0	4.03	1 5	43	15	.....	....	....	1,500	....	....	65	65	
" 23	20.0	3.96	1.7	111	20	.208	.110	47.1	2,500	55	50	85	65	
" 24	20.0	3.97	1.9	136	27	3.7	2.2	40.6	2,100	75	70	110	85	
" 25	20.0	4.17	2.1	95	20				2,400	95	75	60	75	

* Closed inlet May 2, 8 A. M.; closed outlet May 2, 12 P. M. Opened inlet, after scraping. May 3, 2:30 P. M.; opened outlet May 3, 6:15 P. M.

Daily Record of the Operation and Efficiency of Filter No. 6.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
May	26	20.0	4.07	2.4	73	18	.138 / 3.0	.076 / 1.8	44.9 / 40.0	2,200	70	65	75	70	96 8
·	27	20.0	4.08	2.5	64	8				2,400	70	80	lost	75	96.9
·	28	22.0	4.03	2.7	50	9				1,900	95	70	....	80	95 8
·	29	22.0	4.01	2.9	82	10	.....	....	....	2,900	....	....	90	90	96.9
·	30	22.0	4.00	3.1	62	12	.....	....	....	3,600	....	....	65	65	98 2
·	31	22.0	4.03	3.2	51	13	.152 / 2 8	.076 / 1.8	50.0 / 35 7	1,500	55	60	....	60	96.0

Daily Record of the Operation and Efficiency of Filter No. 7.

March	28	11.0	2.76	....	169	....	.238 / 5.0	.140 / 2.7	41.2 / 46.0	.....	.....	....	6,600	6,600	....
·	29	11.0	2.64	....	140	20				16,600	5,100	....	2,400	3,800	77.1
·	30	10.5	2.72	0 3	115	25				11,200	4,300	3,400	3,300	3,600	67.8
·	31	9.0	2.53	0.4	171	30	.226 / 4.7	.158 / 3 4	30.1 / 27.7	5,700	1,000	2,200	2,700	2,000	64.9
April	1	9.0	2.54	0.4	86	35				9,500	3,000	1,700	1,200	2,000	78.9
·	2	9 5	2.56	0.4	83	30				4,700	1,900	1,000	....	1,400	70.2
·	3	9.5	2.61	0.4	75	25	.....	....	....	6,100	....	....	1,000	1,000	83.6
·	4	9.0	2.65	0.5	80	20				4,100	1,200	1,000	1,400	1,200	70.7
·	5	7.0	2.47	0.6	75	20	.166 / 3.5	.114 / 2.5	31.3 / 28.6	3,600	850	850	800	850	76.4
·	6	6 5	2.53	0.7	40	15				3,500	1,000	1,200	650	950	72.8
·	7	6.0	2.59	0.8	52	10				3,400	650	400	550	550	83.8
·	8	7.0	2.57	0.9	90	8	.165 / 3.4	.084 / 1.8	49.1 / 47.0	2,700	600	650	500	600	77.8
·	9	8.0	2.57	1.1	50	10				2,100	550	450	....	500	76.2
·	10	8 0	2.55	1.5	92	12	.....	....	....	2,800	....	....	....	....	....
·	11	8.5	2.60	1.8	61	14				3,800	....	130	140	140	96 3
·	12	8.5	2.59	2.2	71	10	.126 / 2.8	.070 / 1.4	44.5 / 50.0	1,900	220	80	110	140	92.6
·	13	9.0	2.51	2.7	65	9				2,200	100	150	210	150	93.2
·	14	8.5	2.65	2.8	86	8	.102 / 2.3	.064 / 1.3	37.3 / 43.4	2,400	180	130	140	150	93.8
·	15	9.0	2.65	2.8	39	8				2,300	120	250	350	240	89.6
·	16	10.0	2.64	2.9	43	8				3,500	100	150	....	120	96.6
·	17	13.0	2.69	2.9	34	10	.....	....	....	2,700	....	....	190	190	93 0
·	18	13.0	2.64	3.0	23	6				4,400	160	250	275	230	94.8
·	19	13.0	2.61	3.0	26	7	.086 / 1.5	.056 / 1.1	34.8 / 26.7	3,700	100	150	200	150	95.9
·	20	11.5	2.64	3.2	30	4				5,800	210	120	220	180	96 9
·	21	11.5	2.61	3.3	30	3	.080 / 1.6	.054 / 1 1	32.5 / 31.2	5,900	210	180	85	160	97 3
·	22	12.0	2.69	3.6	33	3				5,700	70	160	130	120	97.9
·	23	13.0	2.66	3.8	28	3				6,300	160	160	....	160	97.5
·	24	12.5	2.62	4.0	25	4	.....	....	....	6,100	....	....	180	180	97 0
·	25	12.0	2.65	4.5	31	3				7,700	90	95	190	120	98.4
·	26	13 0	2.60	5.6	27	2	.102 / 2.1	.054 / 1.2	47.1 / 42.9	5,300	85	100	275	150	97.2
·	27	11.5	2.66	6.0	25	3				12,200	160	220	120	170	98.6
·	28	12.0	2.60	6.2	17	3	.124 / 2.3	.066 / 1 3	46.8 / 43.5	9,600	170	180	130	160	98 3
·	29	12.0	2.57	7.3	28	3				6,000	160	180	160	170	97.2
·	30	13 0	2.60	8.4	9	3				4,100	95	120	....	110	97.3
May	1	14.0	2.54	11.6	37	4	.....	....	....	8,900	....	....	200	200	97.8
·	2	15.5	1.65	*	37	3				4,500	160	110	140	130	96.9
·	3	16.0	0.59	0.3	80	5	.136 / 3.2	.076 / 1.7	44.2 / 46.9	6,200	....	....	240	200	96.8
·	4	15.5	1.61	0.8	38	7				3,300	250	140	150	180	94.5
·	5	15.0	2.65	0.3	21	6				2,100	120	100	100	110	94.8
·	6	14.0	2.65	0.3	19	8	.118 / 2 8	.074 / 1.7	37.4 / 39.3	2,900	110	140	46	100	96 5
·	7	11.0	2.66	0.3	23	8				1,900	110	120	....	120	93.7
·	8	11 0	2.65	0.3	30	6	.....	....	....	2,700	....	....	80	80	97.0

* Closed inlet May 1, 12 P. M.; closed outlet May 2, 12 P. M. Opened inlet, after scraping, May 3, 2:30 P. M.; opened outlet May 3, 6:15 P. M.

Daily Record of the Operation and Efficiency of Filter No. 7.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
May 9	12.0	2.61	0.5	24	5	.196	.088	55.1	2,300	90	230	220	180	92
" 10	13.0	2.62	0.5	129	20	3.7	2.3	37.8	15,300	250	170	210	210	99
" 11	14.0	2.61	0.6	82	18				12,200	150	150	160	150	98
" 12	14.0	2.59	0.6	68	9	.152	.084	44.8	8,000	100	70	95	90	99
" 13	14.0	2.62	0.7	52	9	3.5	1.9	45.7	4,300	80	100	85	90	98
" 14	15.0	2.64	0.7	41	8				3,100	65	65	....	65	97
" 15	16.0	2.62	0.8	53	8	.....	...	....	4,000	....	....	80	80	98
" 16	17.0	2.64	0.9	68	7				4,500	75	80	49	70	98
" 17	17.5	2.67	1.0	36	6	.162	.072	55.6	3,000	60	60	31	50	98
" 18	17.0	2.65	1.1	62	5	3.2	1.4	56.2	2,000	47	50	100	65	97
" 19	19.0	2.61	1.1	53	4				2,600	60	55	55	55	97
" 20	20.0	2.60	1.2	50	3	.116	.076	34.5	1,900	65	75	34	60	97
" 21	20.0	2.80	1.4	51	3	2.5	1.3	48.0	2,000	50	60	....	55	97
" 22	20.0	2.60	1.5	43	5	.....	....	....	1,500	....	....	55	55	96
" 23	20.0	2.67	1.7	111	7				2,500	45	80	55	60	97
" 24	20.0	2.67	1.9	136	9	.208	.102	51.0	2,100	85	75	90	85	96
" 25	20.0	2.63	2.0	95	13	3.7	1.9	48 7	2,400	95	70	95	85	96
" 26	20.0	2.59	2.2	73	13				2,200	80	75	60	70	96
" 27	20.0	2.94	2.4	64	8	.138	.066	52.2	2,400	75	80	85	80	96
" 28	22.0	2.60	2.7	50	8	3.0	1.5	50.0	1,900	70	110	....	90	95
" 29	22.0	2.56	3.2	82	8	.....	....	....	2,900	....	....	100	100	96
" 30	22.0	2.70	3.3	62	8				3,600	....	....	65	65	98
" 31	22.0	2.65	3.6	51	8	.152	.070	53.9	1,500	55	65	75	65	95
June 1	21.0	2.63	3.7	57	8	2.8	1.8	35.7	1,200	75	60	46	60	95
" 2	22.0	2.63	....	40	7				1,100	60	50	60	55	95
" 3	22.0	1.65	*	51	5	.132	.066	50.0	1,300	40	....	....	40	97
" 4	22.0	2.35	0.3	41	3	2.7	1.6	40.7	800	75	80	....	75	91
" 5	23.0	2.59	0.3	30	4				900	....	....	60	60	93
" 6	23.0	2.39	0.3	38	4	.130	.070	46.2	800	33	60	42	45	94
" 7	23.0	2.64	0.3	45	5	2.7	1.5	44.4	700	60	30	46	45	93
" 8	24.0	2.69	0.3	38	5				600	44	44	42	43	92
" 9	24.0	2.60	0.3	27	5	.112	.066	41.0	800	24	50	20	31	96
" 10	25.0	2.65	0.3	16	2	2.3	1.4	39.2	700	26	26	42	31	95
" 11	25.0	2.65	0.3	16	2				800	18	40	....	29	96
" 12	24.0	2.62	0.4	15	2	.116	.052	46 5	700	....	....	41	41	94
" 13	26.0	2.62	0.4	14	2	2.3	1.2	47 9	600	45	49	22	39	93
" 14	26.0	2.58	0.5	17	2				1,000	42	37	37	39	96
" 15	26.0	2.61	0.5	15	1	.116	.070	39.7	800	35	29	27	30	96
" 16	24.0	2.73	0.6	12	1	1.7	1.1	35.4	400	24	19	38	27	93
" 17	25.0	2.68	0.6	10	1				200	34	30	36	33	83
" 18	25.0	2.65	0.6	12	1	.104	.062	40.4	250	23	19	....	21	91
" 19	25.0	2.60	0.7	13	1	1.8	1.0	44.5	200	....	....	22	22	89
" 20	25.0	2.62	0.7	12	1				100	28	16	17	20	80
" 21	25.0	2.60	1.0	10	1	.090	.056	37.8	150	24	17	16	19	87
" 22	23.0	2.58	1.1	8	0	1.5	0.9	40.0	95	13	12	21	15	84
" 23	23.0	2.68	1.3	8	1				110	11	28	21	20	82
" 24	24.0	2.58	1.6	7	1	.090	.056	37.8	190	22	16	25	21	89
" 25	21.0	2.53	3.9	6	2	1.7	1.1	35.3	250	18	15	....	16	93
" 26	24.0	2.64	4.2	45	3				4,400	....	....	19	19	95
" 27	25.0	1.63	†	56	2	.148	.064	56.8	2,400	55	....	....	55	97
" 28	25.0	0.67	0.2	67	2	2.5	1.4	44.0	1,000	....	65	17	41	95
" 29	25.0	2.57	0.2	45	2				1,500	95	42	43	60	96
" 30	25.0	2.61	0.2	57	2	.112	.060	46.4	1,700	45	38	34	39	97
July 1	26.0	2.64	0.2	69	2	2.3	1.2	47.9	1,200	29	20	36	28	97

* Closed inlet June 2, 11:35 P. M.; closed outlet June 3, 10 A. M. Opened inlet, after scraping, June 3, 8:45 P. M.; opened outlet June 4, 2:30 A. M.

† Closed inlet June 27, 12:25 A. M.; closed outlet June 27, 7:55 P. M. Opened inlet, after scraping, June 28, 2:30 P. M.; opened outlet June 28, 5:40 P. M.

Daily Record of the Operation and Efficiency of Filter No. 7.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	* Total Organic Matter. Parts per Million. Subsided Water.	* Total Organic Matter. Parts per Million. Effluent.	* Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
July 2	26.0	2.61	0.3	134	2	.182	.074	59.3	2,100	47	65	....	55	97 4
" 3	26.0	2.60	0.3	111	5	3.3	1.6	51.5	1,500	....	....	70	70	95.3
" 4	26.0	2.71	0.3	88	5				1,200	33	....	40	36	97.0
" 5	26.0	2.60	0.3	68	5	.128	.072	43.8	1,500	38	43	29	37	97.5
" 6	26.0	2.64	0.3	53	6	2.7	1.4	48.2	2,500	55	45	37	46	98.2
" 7	27.0	2.64	0.3	37	6				3,200	40	23	60	41	98.7
" 8	27.0	2.63	0.3	23	5	.134	.076	43.2	550	43	25	40	36	93.5
" 9	27.0	2.62	0.3	59	5	2.6	1.7	34.6	650	32	32	....	32	95.1
" 10	25 0	2.57	0.4	94	6				325	....	....	75	75	76.9
" 11	25.0	2.63	0.4	33	5	.126	.066	47.6	1,400	21	33	46	33	97.6
" 12	24.0	2.63	0.4	36	5	2.3	1.5	34.8	1,200	46	26	17	30	97.5
" 13	24.0	2.62	0.4	38	5				1,500	47	27	22	32	97.9
" 14	24.0	2.58	0.4	28	3	.108	.066	38.9	650	24	39	29	31	95.2
" 15	25.0	2.60	0.4	22	3	2.1	1.2	42.9	600	23	30	30	28	95.3
" 16	26.0	2.63	0.5	16	4				550	55	20	....	38	93.1
" 17	26.0	2.58	0.5	13	2	.114	.066	42.1	950	....	....	34	34	96.4
" 18	26.0	2.62	0.6	16	2	2.1	1.3	38.1	450	36	31	30	32	92.9
" 19	26.0	2.61	0.7	18	2				550	37	43	14	31	94.4
" 20	27.0	2.61	0.8	8	1	.110	.062	43.6	3,200	27	25	17	23	99.3
" 21	27.0	2.58	0.9	16	2	2.2	1.3	41.0	1,100	12	25	29	22	98.0
" 22	27.0	2.50	1.1	23	1				850	18	21	13	17	98.0
" 23	27.0	2.59	1.5	78	2	.188	.064	66.0	4,800	31	21	....	26	99.5
" 24	27 0	2.57	2.4	133	3	3.1	1.2	61.3	8,400	....	....	24	24	99.7
" 25	28.0	2.68	2.7	187	2				5,500	40	18	21	26	99.5
" 26	27.0	2.60	2.9	113	3	.168	.088	47.6	3,300	27	27	24	26	99.2
" 27	28.0	2.60	3.0	90	5	3.0	1.4	53.3	3,600	50	26	26	34	99.1
" 28	28.0	2.62	3.3	66	6				2,500	26	32	16	25	99.0
" 29	27.0	2.60	3.6	70	6	.176	.070	60.2	8,000	24	34	19	26	99.7
" 30	27.0	2.56	*	131	7	3.1	1.4	54.8	3,300	26	25	....	25	99.2
" 31	27.0	0.88	0.3	192	25				2,200	....	....	50	120	97.7
Aug. 1	26.0	2.65	0.3	315	23	.224	.076	66.0	5,400	70	65	85	75	98.6
" 2	26.0	2.58	0.2	185	16	3.5	1.6	54.3	1,100	32	60	70	55	95.0
" 3	26 0	2.58	0.3	76	14				3,200	46	38	49	44	98.6
" 4	26.0	2.54	0.3	189	16	.176	.072	59.1	2,300	40	23	46	36	98.4
" 5	26.0	2.71	0.4	140	15	3.3	1.6	51.5	1,600	49	43	50	47	97.1
" 6	25.0	2.63	0.4	91	13				1,700	41	44	....	42	97.5
" 7	25.0	2.59	0.4	87	10	.....	....	....	2,500	....	....	36	36	98.6
" 8	26.0	2.63	0.5	100	11				4,100	24	49	50	41	99.0
" 9	25.0	2.64	0.6	113	13				4,200	45	49	65	55	98.7
" 10	25.0	1.16	....	176	15	.190	.078	59.0	4,400	50	....	....	50	98.9
" 11	25.0	1.67	0.6	207	14	3.2	1.8	43.8	3,800	....	36	41	38	99.0
" 12	25.0	2.68	0.6	266	23				3,600	160	60	70	95	97.4
" 13	25.0	2.65	0.7	280	25				4,800	55	55	....	55	98.9
" 14	25.0	2.16	....	212	30	.234	.100	57.3	6,100	....	....	44	44	99.3
" 15	24.0	0.44	....	237	....	5.0	2.1	58.0	3,200	....	....	....	....	....
" 16	25.0	0.94	0.2	241	25				2,300	....	48	100	75	96.8
" 17	25.0	1.56	0.3	199	30				3,100	80	120	140	110	96.4
" 18	25.0	2.11	0.5	130	30	.180	.106	41.1	1,600	120	110	80	100	93.8
" 19	24.0	2.51	0.5	100	25	4.4	2.6	41.0	1,700	80	70	100	85	95.0
" 20	24.0	2.58	0.7	143	25				5,100	55	50	....	50	99.0
" 21	25.0	2.60	0.7	136	16				4,800	....	....	37	37	99.2
" 22	25.0	2.67	0.9	137	20	.186	.112	39.8	3,800	65	60	140	90	97.6
" 23	26.0	2.47	0.9	139	18	4.1	2.5	39.0	4,800	70	75	70	70	98.5
" 24	25.0	2.60	1.1	113	17				3,400	60	44	60	55	98.4
" 25	26.0	2.57	1.2	80	18				1,400	40	47	45	44	96.9
" 26	25.0	2.66	1.3	75	20	.155	.092	40.6	1,000	40	60	55	50	95.0
" 27	25.5	2.02	1.3	57	14	3.7	2.0	46.0	1,000	32	49	....	40	96.0
" 28	24.0	2.60	1.4	55	12				1,600	....	....	49	49	97.0

* Closed inlet July 30, 8:30 A. M.; closed outlet July 31, 8 A. M. Opened inlet, after scraping, July 31, 1 P. M.; opened outlet July 31, 4:30 P. M.

Daily Record of the Operation and Efficiency of Filter No. 7.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
Aug. 29	24.5	2.54	1.4	84	11	.166	.086	48.3	1,400	31	60	38	43	96.9
" 30	25.5	2.43	1.4	115	16	3.5	2.0	42.9	1,500	60	34	45	46	96.9
" 31	25.5	2.62	1.6	93	13				1,500	55	60	60	60	96.0
Sept. 1	26.0	2.61	1.6	66	9				2,300	38	36	55	43	98.1
" 2	26.0	2.66	1.7	57	9	.165	.094	43.1	2,200	47	31	29	36	98.4
" 3	27.0	2.69	1.9	53	9	3.9	2.1	46.2	1,700	17	21	....	19	98.9
" 4	28.0	1.28	....	38	10				3,300	....	....	....	....	....
" 5	25.0	....	....	....	....				1,500	....	....	....	....	....
" 6	27.0	0.50	0.3	20	....				1,000	....	....	31	31	96.9
" 7	25.0	1.87	0.6	12	5	.138	.102	26.2	450	65	29	70	55	87.8
" 8	23.0	2.57	0.7	10	6	3.3	2.3	30.4	600	42	42	30	39	93.7
" 9	23.0	2.62	0.7	9	6				850	30	20	18	23	97.3
" 10	22.0	2.59	0.9	14	5				1,500	24	19	....	22	98.5
" 11	22.0	2.69	1.3	12	3	.130	.090	30.8	1,600	....	....	16	16	99.0
" 12	21.0	2.63	1.5	7	2	2.8	1.8	35.1	550	19	10	6	12	97.8
" 13	21.0	2.63	1.7	14	3				220	7	10	12	10	95.5
" 14	21.0	2.60	1.9	10	3				275	10	15	21	15	94.5
" 15	22.0	2.60	2.2	12	3	.118	.070	40.7	2,600	25	16	13	18	99.3
" 16	22.0	2.63	2.6	11	4	2.0	1.5	25.0	2,100	28	22	16	22	99.0
" 17	21.0	2.69	3.1	12	1				1,400	30	24	....	27	98.1
" 18	22.0	2.65	3.7	18	2				4,200	....	....	22	22	98.5
" 19	22.0	2.56	3.8	33	3	.114	.070	38.6	2,200	27	30	39	32	98.5
" 20	21.0	0.94	0.5	11	1	2.2	1.4	36.4	1,900	29	....	80	70	96.3
" 21	22.0	2.66	0.5	10	1				1,400	95	75	130	100	92.9
" 22	23.0	2.65	0.6	16	2				1,200	42	47	34	41	96.6
" 23	22.0	2.62	0.6	27	1	.122	.078	36.1	5,000	24	17	43	28	99.4
" 24	23.0	2.60	0.4	30	1	2.1	1.6	23.8	4,200	35	47	....	41	99.0
" 25	22.0	0.91	0.6	15	1				.....	....	....	....	....	....

Permanently stopped September 25, 8:30 A. M.

Daily Record of the Operation and Efficiency of Filter No. 8.

March 28	11.0	2.80	0.2	169	....	.....	....	....	.....	....	3,900	....	3,900	....
" 29	11.0	2.33	0.2	140	25	.238	.118	50.4	16,600	2,200	....	2,200	2,200	86.8
" 30	10.5	2.51	0.2	115	20	5.0	2.8	44.0	11,200	3,900	....	2,700	3,300	70.5
" 31	9.0	2.53	0.2	171	25				5,700	2,200	4,200	1,800	2,700	52.7
April 1	9.0	2.53	0.2	86	30	.226	.148	34.5	9,500	2,500	2,300	1,300	2,000	78.9
" 2	9.5	2.55	0.2	83	35	4.7	3.1	34.1	4,700	1,900	1,900	....	1,900	59.6
" 3	9.5	2.58	0.2	75	30	.....	....	....	6,100	....	....	1,600	1,600	73.8
" 4	9.0	2.56	0.2	80	25	.166	.132	20.5	4,100	900	2,100	1,300	1,400	65.8
" 5	7.0	2.55	0.3	75	20	3.5	2.2	37.2	3,600	2,100	1,000	1,000	1,400	61.1
" 6	6.5	2.52	0.4	40	15				3,500	1,200	1,500	750	1,200	65.7
" 7	6.0	2.59	0.5	52	15	.165	.062	62.4	3,400	1,100	1,600	850	1,200	64.7
" 8	7.0	2.54	0.6	90	15	3.4	2.0	41.2	2,700	700	900	750	800	70.3
" 9	8.0	2.56	0.7	50	15				2,100	1,100	650	....	900	57.2
" 10	8.0	2.62	0.9	92	18	.....	....	....	2,800	....	....	275	275	90.2
" 11	8.5	2.67	1.1	61	20	.126	.074	41.3	3,800	325	425	300	350	90.8
" 12	8.5	2.63	1.3	71	22	2.8	1.3	53.6	1,900	200	160	100	150	92.1
" 13	9.0	2.57	1.6	65	20				2,200	110	140	240	160	92.7
" 14	8.5	2.68	1.7	86	15	.102	.058	43.2	2,400	180	200	120	170	92.9
" 15	9.0	2.65	1.9	39	10	2.3	1.3	43.4	2,500	120	200	375	230	90.8
" 16	10.0	2.63	1.9	43	8				3,500	250	210	....	230	93.4
" 17	13.0	2.59	2.0	34	6	.....	....	....	2,700	....	....	250	250	90.7
" 18	13.0	2.65	2.0	23	5	.086	.060	30.2	4,400	220	210	325	250	94.3
" 19	13.0	2.60	2.1	26	4	1.5	1.2	20.0	3,700	170	180	180	180	95.1
" 20	11.5	2.64	2.4	30	5				5,800	170	160	150	160	97.2

Daily Record of the Operation and Efficiency of Filter No. 8.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million.		Total Organic Matter. Parts per Million.			Bacteria per Cubic Centimeter.					Average Bacterial Efficiency.
					Subsided Water.	Effluent.	Subsided Water.	Effluent.	Percentage Removal.	Subsided Water.	Effluent. 8 A M	4 P M	12 P M	Average.	
April	21	11.5	2.60	2.4	30	6	.080	.060	25.0	5,900	375	220	160	250	95.8
"	22	12.0	2.60	2.6	33	3	1.6	1.2	25.0	5,700	130	200	220	180	96.8
"	23	13.0	2.57	2.7	28	4				6,300	130	180	....	160	97.5
"	24	12.5	2.55	2.8	25	4	.....	....	....	6,100	....	....	100	100	98.4
"	25	12.0	2.63	3.2	31	3	.102	.048	52.9	7,700	160	70	160	130	98.3
"	26	13.0	2.68	3.8	27	4	2.1	1.2	42.9	5,300	150	180	150	160	97.0
"	27	11.5	2.58	4.2	25	3				12,200	100	230	120	150	98.8
"	28	12.0	2.59	4.7	17	3	.124	.070	43.6	9,600	130	160	160	150	98.4
"	29	12.0	2.64	5.3	28	2	2.3	1.4	39.1	6,000	120	140	160	140	97.7
"	30	13.0	2.64	6.1	9	3				4,100	170	90	....	130	96.8
May	1	14.0	2.65	6.6	37	3	....	....	....	8,900	....	....	160	160	98.2
"	2	15.5	2.62	9.9	37	4	.136	.076	44.2	4,500	100	110	95	100	97.8
"	3	16.0	1.53	*	80	6	3.2	1.7	46.9	6,200	180	240	250	220	96.5
"	4	15.5	0.93	0.2	38	5				3,300	325	....	250	300	90.9
"	5	15.0	2.61	0.2	21	5	.118	.074	37.4	2,100	190	130	50	120	94.3
"	6	14.0	2.60	0.2	19	13	2.8	1.7	39.3	2,900	75	90	75	80	97.2
"	7	11.0	2.59	0.2	23	8				1,900	120	120	....	120	93.7
	8	11.0	2.47	0.2	30	8	.....	....	....	2,700	....	....	110	110	95.9
"	9	12.0	2.64	0.2	24	7	.196	.088	55.1	2,300	130	95	275	170	92.6
"	10	13.0	2.52	0.2	129	25	3.7	2.2	40.5	15,300	350	350	250	325	97.9
"	11	14.0	2.64	0.3	82	18				12,200	210	180	200	200	98.4
"	12	14.0	2.66	0.3	68	16				8,000	150	95	95	110	98.6
"	13	14.0	2.73	0.3	52	18	.152	.086	43.4	4,300	120	100	50	90	97.9
"	14	15.0	2.74	0.3	41	9	3.5	2.1	40.0	3,100	85	65	....	75	97.6
"	15	16.0	2.75	0.4	53	9				4,000	....	....	75	75	98.1
"	16	17.0	2.73	0.4	68	8	.....	....	....	4,500	85	55	65	70	98.4
"	17	17.5	2.73	0.4	36	6	.162	.078	51.8	3,000	35	75	50	55	98.2
"	18	17.0	2.77	0.5	62	5	3.2	1.6	50.0	2,000	37	28	130	65	96.7
"	19	19.0	2.75	0.5	53	5				2,600	55	110	80	80	96.9
"	20	20.0	2.72	0.5	50	4	.116	.078	32.8	1,900	85	100	75	85	95.5
"	21	20.0	2.71	0.5	51	4	2.5	1.5	40.0	2,000	80	65	....	70	96.5
"	22	20.0	2.55	0.5	43	5				1,500	....	....	60	60	96.0
"	23	20.0	2.53	0.6	111	8	.....	....	....	2,500	65	60	100	75	97.0
"	24	20.0	2.64	0.7	136	16	.209	.106	49.1	2,100	70	95	100	90	95.7
"	25	20.0	2.75	0.8	95	25	3.7	2.1	43.3	2,400	150	120	110	130	94.6
"	26	20.0	2.67	0.9	73	16				2,200	85	120	100	100	94.5
"	27	20.0	2.67	1.0	64	9	.138	.068	50.7	2,400	85	130	130	120	95.0
"	28	22.0	2.66	1.0	50	9	3.0	1.7	43.3	1,900	85	130	....	110	94.2
"	29	22.0	2.65	1.1	82	10	.....	....	....	2,900	....	....	160	160	94.5
"	30	22.0	2.64	1.1	62	11	.....	....	....	3,600	....	....	120	120	96.7
"	31	22.0	2.64	1.2	51	13	.152	.074	51.3	1,500	95	110	100	100	93.3
June	1	21.0	2.63	1.2	57	9	2.8	1.7	39.3	1,200	....	....	75	75	93.8
"	2	22.0	2.61	1.2	40	8				1,100	65	46	80	65	94.1
"	3	22.0	2.48	1.5	51	8	.132	.070	47.0	1,300	60	45	65	55	95.8
"	4	22.0	2.56	1.6	41	4	2.7	1.7	37.0	800	45	28	....	36	95.6
"	5	23.0	2.67	1.6	30	4				900	....	....	24	39	95 7
	6	23.0	2.62	1.7	38	3	.130	.068	47 7	800	46	44	46	45	94.4
"	7	23.0	2.59	1.7	45	5	2.7	1.4	48.2	700	44	38	41	62	91.1
"	8	24.0	2.60	1.8	38	5				600	44	34	24	34	94.3
"	9	24.0	2.65	1.8	27	4	.112	.070	37.5	800	25	37	24	29	96.4
"	10	25.0	2.64	1.9	16	2	2.3	1.3	43.5	700	27	23	26	25	96.4
"	11	25.0	2.60	2.0	16	2				800	40	26	....	33	95.9
"	12	25.0	2.56	2.4	15	1	.116	.062	46.5	700	....	....	37	37	94.7
"	13	26.0	2.56	2.9	13	1	2.3	1.3	43.5	600	35	23	41	33	94.5
"	14	26.0	2.62	3.3	17	1				1,000	41	34	27	34	96.6
"	15	26.0	2.62	3.5	15	1	.116	.076	34.5	800	36	25	42	34	95.8
"	16	24.0	2.61	3.9	12	2	1.7	1.1	35.4	400	22	31	46	33	91.8

* Closed inlet May 1, 12 P. M.; closed outlet May 2, 12 P. M. Opened inlet, after scraping, May 3, 2:30 P. M.; opened outlet May 3, 6:15 P. M.

Daily Record of the Operation and Efficiency of Filter No. 8.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
June 17	24.0	1.91	*	10	1	.104	.062	40.4	200	28	50	....	39	80.5
" 18	25.0	0.82	0.1	12	1	1.8	1.0	44.5	250	....	....	....	100	60.0
" 19	25.0	2.68	0.1	13	1				200	....	....	240	240	—20.0
" 20	25.0	2.57	0.1	12	1	.090	.058	35.5	100	130	170	100	130	—30.0
" 21	25.0	2.54	0.1	10	1	1.5	0.9	40.0	150	75	80	70	75	50.0
" 22	23.0	2.58	0.1	8	1				95	40	36	46	41	56.8
" 23	23.0	2.61	0.1	8	0	.090	.058	35.6	110	37	31	26	31	71.8
" 24	24.0	2.55	0.1	7	1	1.7	1.1	35.3	190	32	28	49	36	81.0
" 25	24.0	2.65	0.2	6	2				250	23	21	....	22	91.2
" 26	24.0	2.53	0.2	45	2	.148	.074	50.0	4,400	....	....	55	55	98.8
" 27	25.0	2.65	0.2	56	2	2.5	1.4	44.0	2,400	24	18	25	22	99.1
" 28	25.0	2.43	0.4	67	2				1,000	33	27	22	27	97.3
" 29	25.0	2.37	0.5	45	2	.112	.060	46.4	1,560	25	30	26	27	98.2
" 30	25.0	2.49	0.6	57	2	2.3	1.4	39.2	1,700	55	42	lost	48	97.2
July 1	26.0	2.60	0.9	69	2				1,200	120	67	100	95	92.1
" 2	26.0	2.55	1.0	134	5	.182	.078	57.1	2,100	55	49	....	50	97.6
" 3	26.0	2.55	1.1	111	6	3.3	1.7	48.5	1,500	....	....	65	65	95.7
" 4	26.0	2.57	1.1	88	4				1,200	40	....	31	35	97.1
" 5	26.0	2.56	1.0	68	6	.128	.074	42.2	1,500	50	29	48	42	97.2
" 6	26.0	2.65	1.1	53	8	2.7	1.6	40.8	2,500	41	34	39	38	98.5
" 7	27.0	2.62	1.0	37	6				3,200	28	44	43	38	98.8
" 8	27.0	2.62	0.7	23	6	.134	.078	41.8	550	26	39	27	31	94.4
" 9	27.0	2.69	1.0	59	6	2.6	1.6	38.5	650	33	31	....	32	95.1
" 10	25.0	2.63	1.2	94	6				325	....	....	33	33	89.9
" 11	25.0	2.65	1.3	33	6	.126	.074	41.3	1,400	25	32	23	27	98.1
" 12	24.0	2.67	1.5	36	3	2.3	1.5	34.8	1,200	48	36	36	40	96.7
" 13	24.0	2.59	1.8	38	6				1,500	32	33	22	29	98.1
" 14	24.0	2.60	1.8	28	5	.108	.070	35.2	650	31	84	36	34	94.8
" 15	25.0	2.62	2.2	22	3	2.1	1.3	38.1	600	32	37	30	33	94.5
" 16	26.0	2.62	2.6	16	3				550	43	37	....	40	92.7
" 17	26.0	2.54	2.6	13	3	.104	.066	42.1	950	....	....	17	17	98.2
" 18	26.0	2.57	3.0	16	3	2.1	1.2	42.9	450	31	40	33	35	92.2
" 19	26.0	2.66	3.2	18	2				550	39	43	34	39	92.9
" 20	27.0	2.67	3.5	8	2	.110	.064	41.8	3,200	25	39	95	55	98.3
" 21	27.0	2.57	†	16	3	2.2	1.3	41.0	1,100	46	42	75	55	95.0
" 22	27.0	1.02	....	23	3				850	60	....	....	60	92.9
" 23	27.0	1.88	0.2	78	2	.188	.072	61.7	4,800	....	....	190	190	96.0
" 24	27.0	2.55	0.2	133	8	3.1	1.5	51.6	8,400	....	....	65	65	99.2
" 25	28.0	2.52	0.2	187	9				5,500	85	80	60	75	98.6
" 26	27.0	2.59	0.2	113	12	.168	.092	45.3	3,300	43	70	75	65	98.0
" 27	28.0	2.54	0.2	90	11	3.0	1.5	50.0	3,600	85	55	60	65	98.2
" 28	28.0	2.64	0.2	66	14				2,500	60	50	46	50	98.0
" 29	27.0	2.59	0.2	70	15	.176	.082	53.4	8,000	60	55	65	60	99.2
" 30	27.0	2.64	0.2	131	15	3.1	1.6	48.4	3,300	47	65	....	55	98.3
" 31	27.0	2.44	0.3	192	23				2,200	....	....	43	43	98.0
Aug. 1	26.0	2.54	0.3	315	23	.224	.082	63.4	5,400	48	60	55	55	99.0
" 2	26.0	2.53	0.3	185	20	3.5	1.6	54.3	1,100	40	45	60	48	95.6
" 3	26.0	2.48	0.3	76	14				3,200	45	55	70	55	98.3
" 4	26.0	2.50	0.3	189	18	.176	.076	56.8	2,300	65	55	70	65	97.2
" 5	26.0	2.61	0.3	140	20	3.3	1.5	54.6	1,600	50	60	55	55	96.6
" 6	25.0	2.59	0.3	91	15				1,700	70	65	....	70	95.9
" 7	25.0	2.59	0.3	87	20	.....	....	....	2,500	....	....	65	65	97.4
" 8	26.0	2.60	0.4	100	18				4,100	65	75	70	70	98.3
" 9	25.0	2.60	0.5	113	20	.190	.082	56.9	4,200	80	50	85	70	98.3
" 10	25.0	2.60	0.5	176	19	3.2	1.6	50.0	4,400	60	42	80	60	98.6
" 11	25.0	2.53	....	207	23				3,800	55	45	70	55	98.6
" 12	25.0	0.17	....	266	....				3,600	....	....	....	....	....

* Closed inlet June 17, 3:40 A. M.; closed outlet June 17, 5:35 P. M. Opened inlet, after scraping, June 18, 1:05 P. M.; opened outlet June 18, 4 P. M.

† Closed inlet July 21, 5:35 P. M.; closed outlet July 22, 10 A. M. Opened inlet, after scraping, July 22, 6:30 P. M.; opened outlet July 23, 6:30 A. M.

Daily Record of the Operation and Efficiency of Filter No. 8.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
Aug. 13	25.0	0.91	0.1	280	*				4,800	....	110	....	110	97.7
14	25.0	1.54	0.1	212	30	.234	.114	51.3	6,100	....	....	180	180	97.0
15	24.0	1.53	0.1	237	30	5.0	2.5	50.0	3,200	150	100	140	130	95.9
16	25.0	2.01	0.3	241	30				2,300	110	90	85	95	95.9
17	25.0	2.52	0.4	199	25				3,100	120	110	200	140	95.5
18	25.0	2.49	0.4	130	30	.180	.108	40.0	1,600	120	110	80	100	93.8
19	24.0	2.55	0.5	100	25	4.4	2.6	41.0	1,700	85	70	90	80	95.3
20	24.0	2.63	0.5	143	25				5,100	100	75	....	85	98.3
21	25.0	2.59	0.6	136	18				4,800	....	....	50	50	99.0
22	25.0	2.66	0.7	137	20	.186	.108	42.0	3,800	130	49	130	100	97.4
23	26.0	2.63	....	139	16	4.1	2.2	46.4	4,800	190	85	80	120	97.6
24	25.0	0.70	....	113	....				.....	....	....	....	....	....

Permanently stopped August 24, 8 A. M.

Daily Record of the Operation and Efficiency of Filter No. 9.

March 28	11.0	2.55	0.2	169	....				....	....	2,200	....	2,200	....
29	11.0	2.50	0.2	140	50	.238	.168	29.4	16,600	3,200	....	2,200	2,700	83.7
30	10.5	2.56	0.2	115	45	5.0	3.5	30.0	11,200	2,200	1,800	1,700	1,900	83.0
31	9.0	2.60	0.3	171	40				5,700	900	2,500	1,200	1,500	73.7
April 1	9.0	2.59	2.3	86	35	.226	.170	24.7	9,500	2,800	1,600	1,300	1,900	80.0
2	9.5	2.59	0.3	83	30	4.7	3.5	25.5	4,700	1,800	1,500	....	1,600	66.0
3	9.5	2.47	0.3	75	25	.....	....	....	6,100	....	....	1,200	1,200	80.4
4	9.0	2.59	0.3	80	20	.166	.130	21.7	4,100	600	1,000	1,200	950	76.8
5	7.0	2.56	0.4	75	15	3.5	2.6	25.7	3,600	1,100	800	850	900	75.0
6	6.5	2.55	0.4	40	16				3,500	1,000	850	475	750	78.6
7	6.0	2.57	0.5	52	14				3,400	500	500	475	500	85.3
8	7.0	2.58	0.6	90	12	.165	.082	50.3	2,700	475	350	600	475	82.4
9	8.0	2.57	0.6	50	16	3.4	2.0	41.2	2,100	450	400	....	425	79.8
10	8.0	2.56	0.9	92	18	.....	....	..	2,800	....	....	250	250	91.1
11	8.5	2.53	1.0	61	22				3,800	230	160	140	180	95.3
12	8.5	2.60	1.2	71	20	.126	.062	35.0	1,900	160	180	110	150	92.1
13	9.0	2.67	1.4	65	18	2.8	1.4	50.0	2,200	150	100	170	140	93.7
14	8.5	2.64	1.5	86	14				2,400	180	110	190	160	93.3
15	9.0	2.62	1.6	39	12	.102	.068	33.4	2,300	140	120	160	140	93.9
16	10.0	2.60	1.7	43	10	2.3	1.3	43.4	3,500	200	170	....	180	94.9
17	13.0	2.59	1.7	34	6	.....	....	....	2,700	....	....	170	170	93.7
18	13.0	2.60	1.6	23	5				4,400	120	150	350	210	95.2
19	13.0	2.59	2.0	26	5	.086	.054	37.2	3,700	220	190	200	200	94.6
20	11.5	2.61	2.2	30	4	1.5	1.1	26.7	5,800	240	170	200	200	96.6
21	11.5	2.58	2.2	30	4				5,900	220	200	110	180	97.0
22	12.0	2.62	2.3	33	3	.080	.056	30.0	5,700	110	140	210	150	97.4
23	13.0	2.62	2.5	28	4	1.6	1.0	37.5	6,300	140	140	....	140	97.8
24	12.5	2.57	2.6	25	4	.....	....	....	6,100	....	....	100	100	98.4
25	12.0	2.59	2.8	31	5				7,700	90	70	140	100	98.7
26	13.0	2.64	3.5	27	4	.102	.062	39.2	5,300	120	90	100	100	98.1
27	11.5	2.70	3.8	25	4	2.1	1.2	42.9	12,200	120	210	170	170	98.6
28	12.0	2.60	4.2	17	4				9,600	170	150	90	140	98.5
29	12.0	2.58	5.0	28	8	.124	.070	43.6	6,000	130	110	180	140	97.7
30	13.0	2.66	5.2	9	4	2.3	1.4	39.1	4,100	85	75	....	80	98.0
May 1	14.0	2.54	5.6	37	3	.....	....	....	8,900	....	....	170	170	98.1
2	15.5	2.61	7.9	37	3				4,500	75	80	110	90	98.0
3	16.0	2.32	†	80	8	.136	.076	44.2	6,200	110	110	130	120	98.1
4	15.5	0.97	....	38	4	3.2	1.7	46.9	3,300	190	130	120	150	95.5

* Closed inlet August 11, 9:50 A. M.; closed outlet August 12, 1:45 A. M. Opened inlet, after scraping, August 12, 5:30 P. M.; opened outlet August 13, 3 A. M.

† Closed inlet May 3, 5 P. M.; closed outlet May 4, 12 P. M. Opened inlet, after scraping, May 5, 2:50 P. M.; opened outlet May 5, 7:40 P. M.

Daily Record of the Operation and Efficiency of Filter No. 9.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
May	5	15.0	0.50	0.2	21	12	2.8	1.8	35.7	2,100	....	....	140	130	93.8
"	6	14.0	2.62	0.2	19	9	118	.076	35.7	2,900	120	100	130	120	95.9
"	7	11.0	2.45	0.2	23	13				1,900	180	140	....	160	91.6
"	8	11.0	2.84	0.2	30	10	.....	....	....	2,700	....	....	85	85	96.8
"	9	12.0	2.72	0.2	24	8				2,300	160	475	350	325	85.9
"	10	13.0	2.70	0.3	129	30	3.7	2.1	43.2	15,300	110	450	450	325	97.9
"	11	14.0	2.72	0.3	82	20	.196	.088	55.1	12,200	400	300	240	325	97.3
"	12	14.0	2.68	0.3	68	23				8,000	170	140	110	140	98.2
"	13	14.0	2.66	0.3	52	16	.152	.094	38.2	4,300	140	90	100	110	97.4
"	14	15.0	2.61	0.3	41	13	3.5	2.2	37.2	3,100	75	80	....	80	97.4
"	15	16.0	2.53	0.4	53	12	.....	....	....	4,000	....	....	90	90	97.8
"	16	17.0	2.58	0.4	68	8				4,500	90	90	75	85	98.1
"	17	17.5	2.74	0.4	36	7	.162	.080	50.6	3,000	60	70	50	60	98.0
"	18	17.0	2.74	0.5	62	5	3.2	1.5	53.1	2,000	50	55	85	65	96.7
"	19	19.0	2.73	0.5	53	6				2,600	75	100	80	85	96.7
"	20	20.0	2.71	0.5	50	5	.116	.076	34.5	1,900	50	60	65	60	96.8
"	21	20.0	2.72	0.5	51	5	2.5	1.3	48.0	2,000	45	34	....	39	98.0
"	22	20.0	2.68	0.5	43	6	.....	....	....	1,500	....	....	60	60	96.0
"	23	20.0	2.71	0.7	111	8				2,500	60	50	70	60	97.6
"	24	20.0	2.71	0.8	136	25	.208	.106	49.1	2,100	60	70	95	75	96.4
"	25	20.0	2.69	0.9	95	25	3.7	2.1	43.3	2,400	110	60	90	85	96.5
"	26	20.0	2.74	1.0	73	20				2,200	80	110	65	85	96.1
"	27	20.0	2.60	1.1	64	9	.138	.072	47.8	2,400	50	100	110	85	96.5
"	28	22.0	2.65	1.2	50	13	3.0	1.7	43.3	1,900	85	80	....	80	95.8
"	29	22.0	2.64	1.3	82	12	.....	....	....	2,900	....	....	70	70	97.6
"	30	22.0	2.61	1.4	62	10	.....	....	....	3,600	....	....	80	80	97.8
"	31	22.0	2.71	1.4	51	13	.152	.078	48.7	1,500	65	75	....	70	95.3
Aug.	1	26.0	1.29	0.1	315	16	2.8	1.7	39.3	5,400	....	550	700	800	85.2
"	2	26.0	2.56	0.2	185	13	.224	.078	65.2	1,100	600	650	1,600	950	14.6
"	3	26.0	2.64	0.2	76	13	3.5	1.7	51.4	3,200	300	190	350	275	91.4
"	4	26.0	2.64	0.2	189	23				2,300	200	150	....	170	92.6
"	5	26.0	2.63	0.2	140	22	.176	.084	52.3	1,600	110	110	150	120	92.5
"	6	25.0	2.62	0.2	91	16	3.3	1.7	48.5	1,700	120	100	....	110	93.5
"	7	25.0	2.69	0.2	87	16	.....	....	....	2,500	....	....	130	130	94.8
"	8	26.0	2.70	0.2	100	17				4,100	130	90	100	110	97.3
"	9	25.0	2.70	0.3	113	20				4,200	100	80	100	95	97.7
"	10	25.0	2.65	0.3	176	23	.190	.082	56.9	4,400	65	55	200	110	97.5
"	11	25.0	2.47	*	207	25	3.2	1.8	43.8	3,800	300	75	110	160	95.8
"	12	25.0	....	....	....	....				3,600	....	....	....	....	....
"	13	25.0	....	....	....	....				4,800	....	....	....	....	....
"	14	25.0	0.92	0.1	212	30	.231	.118	49.6	6,100	....	....	300	180	97.0
"	15	24.0	1.52	0.1	237	30	5.0	2.4	52.0	3,200	160	180	160	170	94.7
"	16	25.0	2.20	0.1	241	30				2,300	170	150	250	190	91.7
"	17	25.0	2.59	0.1	199	30				3,100	200	275	220	230	92.6
"	18	25.0	2.69	0.1	130	30	.180	.112	37.8	1,600	190	160	240	200	87.5
"	19	24.0	2.62	0.1	100	25	4.4	2.9	34.1	1,700	170	85	46	100	94.1
"	20	24.0	2.58	0.2	143	25				5,100	140	90	....	110	97.8
"	21	25.0	2.62	0.2	136	23				4,800	....	....	140	140	97.1
"	22	25.0	2.62	0.2	137	25	.186	.120	35.5	3,800	120	170	190	160	95.8
"	23	26.0	2.60	0.2	139	20	4.1	2.5	39.0	4,800	140	100	150	130	97.3
"	24	25.0	2.66	0.2	113	23				3,400	150	150	180	160	95.3
"	25	26.0	2.65	0.2	80	25				1,400	115	120	170	135	90.4
"	26	25.0	2.65	0.2	75	23	.155	.092	40.6	1,000	170	110	90	120	88.0
"	27	25.5	2.53	0.2	57	18	3.7*	2.1	43.3	1,000	80	65	....	70	93.0
"	28	24.0	2.45	0.2	55	16				1,600	....	....	95	95	94.1
"	29	24.5	2.63	0.3	84	15				1,400	80	65	75	75	94.6
"	30	25.5	2.62	0.3	115	20	.166	.108	35.0	1,500	110	130	100	110	92.7
"	31	25.5	2.66	0.3	93	18	3.5	2.2	37.2	1,500	90	90	100	95	93.7

* Closed inlet August 11, 9:50 A. M.; closed outlet August 12, 12:40 A. M. Opened inlet, after scraping, August 13, 6:15 P. M.; opened outlet August 14, 9 A. M.

Daily Record of the Operation and Efficiency of Filter No. 10.

Date. 1898.	Temperature, Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent.[2] 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
March 28	11.0	2.65	0.2	169	....	.238	.116	51.3	.....	....	5,200	....	5,200	....
" 29	11.0	1.05	0.2	140	30	5.0	2.4	52.0	16,600	4,400	....	4,600	4,500	73.5
" 30	10.5	1.51	0.2	115	25				11,200	2,000	3,500	4,400	3,300	70.5
" 31	9.0	1.52	0.2	171	25	.226	.148	34.5	5,700	2,800	1,500	3,000	2,400	57.9
April 1	9.0	1.52	0.3	86	25	4.7	3.0	36.1	9,500	2,500	3,700	1,000	2,400	74.7
" 2	9.5	1.54	0.3	83	20				4,700	2,000	2,500	....	2,200	53.2
" 3	9.5	1.56	0.3	75	18	.....	....	....	6,100	....	....	1,000	1,000	83.6
" 4	9.0	1.56	0.3	80	16	.166	.124	25.3	4,100	1,300	1,400	1,300	1,300	68.3
" 5	7.0	1.55	0.3	75	14	3.5	2.1	40.0	3,600	600	800	900	750	79.2
" 6	6.5	1.55	0.4	40	16				3,500	700	1,100	850	900	74.6
" 7	6.0	1.52	0.4	52	15	.165	.078	52.7	3,400	850	600	600	700	79.4
" 8	7.0	1.45	0.4	90	13	3.4	1.8	47.0	2,700	600	400	600	550	79.6
" 9	8.0	1.55	0.5	50	12				2,100	650	800	....	700	66.7
" 10	8.0	1.52	0.7	92	11	.....	....	....	2,800	....	....	....	....	....
" 11	8.5	1.53	0.8	61	10	.126	.072	42.8	3,800	....	250	350	300	92.1
" 12	8.5	1.60	1.1	71	8	2.8	1.3	53.6	1,900	220	110	95	140	92.6
" 13	9.0	1.59	1.2	65	10				2,200	110	180	220	170	92.3
" 14	8.5	1.57	1.2	86	8	.102	.072	29.5	2,400	210	150	180	180	92.5
" 15	9.0	1.57	1.3	39	6	2.3	1.2	47.8	2,300	130	210	375	240	89.6
" 16	10.0	1.53	1.3	43	5				3,500	220	190	....	200	94.3
" 17	13.0	1.57	1.3	34	4	.....	....	....	2,700	....	....	95	95	96.5
" 18	13.0	1.55	1.3	23	3	.086	.062	27.8	4,400	100	300	275	220	95.0
" 19	13.0	1.53	1.4	26	4	1.5	1.1	26.7	3,700	120	250	140	170	95.4
" 20	11.5	1.55	1.4	30	3				5,800	250	180	270	230	96.0
" 21	11.5	1.54	1.4	30	4	.080	.056	30.0	5,900	350	240	160	250	95.8
" 22	12.0	1.55	1.4	33	4	1.6	1.0	37.5	5,700	120	200	160	160	97.2
" 23	13.0	1.59	1.5	28	3				6,300	250	110	....	180	97.1
" 24	12.5	1.51	1.6	25	3	.....	....	....	6,100	....	....	130	130	97.9
" 25	12.0	1.64	1.8	31	4	.102	.050	51.0	7,700	200	160	120	160	97.9
" 26	13.0	1.36	1.9	27	3	2.1	1.2	42.9	5,300	130	120	180	140	97.4
" 27	11.5	1.57	2.2	25	3				12,200	110	110	160	130	98.9
" 28	12.0	1.53	2.4	17	3	.124	.066	46.8	9,600	220	160	170	180	98.1
" 29	12.0	1.52	2.6	28	2	2.3	1.2	47.8	6,000	180	210	170	190	96.8
" 30	13.0	1.54	2.9	9	4				4,100	180	220	....	200	95.1
May 1	14.0	1.57	3.1	37	3	.....	....	....	8,900	....	....	150	150	98.3
" 2	15.5	1.49	3.7	37	3	.136	.076	44.2	4,500	85	410	140	110	97.6
" 3	16.0	1.54	4.5	80	4	3.2	1.4	56.3	6,200	170	120	180	160	97.4
" 4	15.5	1.54	4.8	38	4				3,300	70	85	160	100	97.0
" 5	15.0	1.57	5.1	21	5	.118	.068	42.5	2,100	120	80	85	95	95.5
" 6	14.0	1.52	5.4	19	5	2.8	1.5	46.4	2,900	36	90	100	75	97.4
" 7	11.0	1.55	6.5	23	5				1,900	70	65	....	70	96.3
" 8	11.0	1.56	6.5	30	5	.....	....	....	2,700	....	....	75	75	97.2
" 9	12.0	1.40	8.3	24	4	.196	.082	58.2	2,300	60	75	100	80	96.5
" 10	13.0	1.52	9.6	129	4	3.7	1.8	51.3	15,300	160	170	180	170	98.9
" 11	14.0	1.47	*	82	6				12,200	200	300	140	210	98.3
" 12	14.0	0 00	....	68	6	.152	.080	47.4	8,000	130	....	110	120	98.5
" 13	14.0	0.54	0.1	52	6	3.5	1.7	51.4	4,300	....	....	140	120	97.2
" 14	15.0	1.62	0.2	41	7				3,100	170	130	....	150	95.2
" 15	16.0	1.59	0.2	53	7	.....	....	....	4,000	....	....	70	70	98.2
" 16	17.0	1.56	0.2	68	7	.162	.070	56.8	4,500	140	190	120	150	96.7
" 17	17.5	1.42	0.2	36	5	3.2	1.4	56.2	3,000	80	95	90	90	97 0
" 18	17.0	1.58	0.2	62	5				2,000	55	50	150	85	95 8
" 19	19.0	1.51	0.2	53	5	.116	.072	38.0	2,600	110	70	85	90	96 5
" 20	20.0	1.54	0.2	50	3	2.5	1.2	52 0	1,900	85	70	100	85	95.5
" 21	20.0	1.55	0.2	51	3				2,000	60	50	....	55	97 2
" 22	20.0	1.57	0.2	43	4	.....	....	....	1,500	....	....	50	50	96.7
" 23	20.0	1.57	0.3	111	5	.208	.094	54.8	2,500	95	75	70	80	96.8
" 24	20.0	1.55	0.3	136	8	3.7	1.6	56.8	2,100	75	70	120	90	95.7
" 25	20.0	1.58	0.4	95	16				2,400	100	75	120	100	95.8

* Closed inlet May 11, 4:35 P. M.; closed outlet May 13, 9 A. M. Opened inlet, after scraping, May 13, 3:25 P. M.; opened outlet May 13, 7 P. M.

Daily Record of the Operation and Efficiency of Filter No. 10.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Bacteria per Cubic Centimeter. Effluent. 4 P M	Bacteria per Cubic Centimeter. Effluent. 12 P M	Bacteria per Cubic Centimeter. Effluent. Average.	Average Bacterial Efficiency.
May	26	20.0	1.56	0.5	73	13	.138	.066	52.2	2,200	130	95	95	110	95
..	27	20.0	1.56	0.6	64	8	3.0	1.6	46.7	2,400	95	70	65	75	96.9
..	28	22.0	1.57	0.7	50	8				1,900	60	80	...	70	96.3
..	29	22.0	1.58	0.8	82	8	.....	....	....	2,900	....	....	80	80	97.2
..	30	22.0	1.57	0.9	62	8	.....	....	....	3,600	....	....	70	70	98.1
..	31	22.0	1.63	1.0	51	8	.152	.068	55.3	1,500	70	60	65	65	95.7
June	1	21.0	1.55	1.0	57	8	2.8	1.5	46.4	1,200	65	65	43	60	95.0
..	2	22.0	1.57	1.0	40	8				1,100	49	42	70	55	95.0
..	3	23.0	1.58	1.1	51	7	.132	.066	50 0	1,300	65	39	36	47	96.4
..	4	22.0	1.58	1.2	41	4	2.7	1.5	44.4	800	27	42	...	34	95.8
..	5	23.0	1.54	1.2	30	4				900	....	....	32	32	96.4
..	6	23.0	1.58	1.3	38	3	.130	.068	47.7	800	35	34	40	36	95.5
..	7	23.0	1.51	1.3	45	5	2.7	1.3	51.9	700	30	43	40	38	94.6
..	8	24.0	1.52	1.3	38	5				600	47	28	36	37	93.8
..	9	24.0	1.52	1.3	27	5	.112	.068	39.3	800	16	37	23	25	96.9
..	10	25.0	1.59	1.3	16	2	2.3	1.3	43.5	700	22	35	31	29	95.8
..	11	25.0	1.58	1.3	16	2				800	28	32	...	30	96.3
..	12	26.0	1.53	1.4	15	2	.110	.058	50.0	700	....	....	39	39	94.4
..	13	26.0	1.53	1.9	14	2	2.3	1.2	47.9	600	21	31	49	34	94.3
..	14	26.0	1.52	2.3	17	2				1,000	22	40	23	28	97.2
..	15	26.0	1.56	2 6	15	1	.116	.066	43.1	800	32	18	25	25	96.9
..	16	24.0	1.55	2.6	12	1	1.7	0.9	47.1	400	14	16	24	18	95.5
..	17	24.0	1.58	2.7	10	1				200	18	26	24	23	88.5
..	18	25.0	1.59	2.9	12	1	.104	.058	44.2	250	39	30	...	34	86.4
..	19	25.0	1.43	3.1	13	1	1.8	0.9	50.0	200	....	....	35	35	82.5
..	20	25.0	1.53	3.2	12	1				100	27	20	10	19	81.0
..	21	25.0	1.54	3 4	10	1	.090	.064	28.9	150	31	17	15	21	86.0
..	22	23.0	1.56	3.6	8	....	1.5	0.9	40.0	95	18	20	34	24	74.7
..	23	23.0	1.53	3 9	8	1				110	35	32	28	32	70.9
..	24	24.0	1.50	*	7	....	.090	.054	40 0	190	25	20	80	42	77.8
..	25	24.0	0.58	0.1	6	...	1.7	1.0	41.2	250	....	....	...	...	
..	26	24.0	1.57	0.1	45	3				4,400	....	....	120	120	97.3
..	27	25 0	1.58	0.1	56	3	.148	.064	56.8	2,400	95	95	47	80	96.7
..	28	25.0	1.58	0.1	67	2	2.5	1.3	48.0	1,000	41	44	65	49	95.1
..	29	25.0	1.55	0.1	45	2				1,500	34	27	60	39	97.4
..	30	25.0	1.54	0.1	57	2	.112	.064	42.9	1,700	41	18	30	44	97.4
July	1	26.0	1.55	0.1	69	2	2.3	1.2	47.9	1,200	17	29	29	25	97.9
..	2	26.0	1.70	0.2	134	2				2,100	33	19	...	26	98.4
..	3	26.0	1.53	0.2	111	2	.182	.062	65.9	1,500	....	....	31	31	97.9
..	4	26.0	1.53	0.2	88	3	3.3	1.7	48.5	1,200	32	....	36	34	97.2
..	5	26.0	1.54	0 2	68	3				1,500	35	36	32	34	97.7
..	6	26.0	1.55	0.3	53	4	.128	.072	43.8	2,500	27	44	22	31	98.5
..	7	27.0	1.55	0.3	37	5	2.7	1.5	44.4	3,200	21	25	27	24	99.3
..	8	27.0	1.58	0.3	23	4				550	29	26	27	27	95.1
..	9	27.0	1.54	0.3	59	3	.134	.074	44.7	650	25	12	...	18	97.2
..	10	25.0	1 65	0.3	94	3	2.6	1.5	42.3	325	....	....	40	40	87.7
..	11	25 0	1.54	0.3	33	3				1,400	24	25	34	28	98.0
..	12	24.0	1.54	0.3	36	3	.126	.062	50.8	1,200	19	20	14	18	98.5
..	13	24.0	1.57	0.3	38	4	2.3	1.4	39.2	1,500	21	22	16	20	99.7
..	14	24.0	1.54	0.3	28	3				650	12	27	24	21	96.8
..	15	25.0	1.55	0 3	22	3	.108	.066	38.9	600	24	15	50	30	95.0
..	16	26.0	1 58	0.4	16	3	2.1	1.2	42.9	550	26	25	...	26	95.3
..	17	26.0	1.54	0 4	13	2				950	....	....	20	20	97.9
..	18	26.0	1.50	0.6	16	3	.114	.062	45.6	450	15	30	24	26	94.2
..	19	26 0	1.55	0.6	18	2	2.1	1.2	42.9	550	27	29	15	23	95.9
..	20	27.0	1 53	0 8	8	2				3,200	11	23	17	17	99.5
..	21	27.0	1.56	1.0	16	2	.110	.058	47.2	1,100	18	13	21	17	99.5
..	22	27.0	1.51	1.5	23	2	2.2	1.1	50.0	850	19	11	16	15	98.2

* Closed inlet June 24, 3:10 A. M.; closed outlet June 25, 3:40 A. M. Opened inlet, after scraping, June 25, 1:30 P. M.; opened outlet June 25, 6:40 P. M.

Daily Record of the Operation and Efficiency of Filter No. 10.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
July 23	27.0	1.53	2 2	78	1	.188	.060	68.1	4,800	29	16	....	22	99.5
" 24	27.0	1.51	3 6	133	2	3.1	1.1	64 5	8,400	....	....	18	18	99.8
" 25	28.0	1.54	*	187	2				5,500	10	13	13	12	99.8
" 26	27.0	1.12	....	113	2	.168	.076	54 8	3,300	20	....	....	20	99.4
" 27	28.0	0.15	0 2	90	2	3 0	1.2	60.0	3,600	....	....	39	39	98.9
" 28	28.0	1.49	0.2	66	2				2,500	41	85	44	55	97.8
" 29	27 0	1.56	0.2	70	2	.176	.072	59.1	8,000	25	17	31	25	99.7
" 30	27.0	1 52	0.2	131	4	3.1	1.2	61.3	3,300	35	20	....	27	99.2
" 31	27.0	1.53	0.2	192	6				2,200	....	....	16	16	99.3

Daily Record of the Operation and Efficiency of Filter No. 11.

March 28	11.0	2.73	0.1	169	....	.238	.096	59.7	.....	....	3,100	....	3,100	....
" 29	11.0	2.11	0.1	140	25	5.0	2.1	58.0	16,600	2,700	....	2,900	2,800	83.1
" 30	10.5	1.52	0.1	115	20				11,200	6,600	7,300	5,600	6,600	41.0
" 31	9.0	1.55	0.2	171	25	.226	.154	31.9	5,700	1,200	4,200	3,800	3,100	45.6
April 1	9.0	1.52	0.2	86	30	4.7	3.1	34.1	9,500	4,000	2,800	1,700	2,800	70.5
" 2	9.5	1.54	0.3	83	30				4,700	2,500	3,400	....	3,000	36.2
" 3	9.5	1.53	0.3	75	25	.....	....	....	6,100	....	....	1,600	1,600	73.8
" 4	9.0	1.53	0.3	80	25	.166	.130	21.7	4,100	900	2,500	1,300	1,600	61.0
" 5	7.0	1.53	0.3	75	25	3.5	2.4	31.4	3,600	1,800	1,900	1,500	1,700	52.8
" 6	6.5	1.56	0.3	40	20				3,500	1,400	1,400	850	1,200	65.7
" 7	6.0	1.53	0.4	52	15	.165	.074	55.2	3,400	1,100	1,300	800	1,100	67.6
" 8	7.0	1.48	0.4	90	13	3.4	2.0	41.2	2,700	650	950	550	700	74.0
" 9	8.0	1.48	0.5	50	12				2,100	750	950	....	850	59 5
" 10	8.0	1.57	0.6	92	14	.....	....	...	2,800	....	....	500	500	82.1
" 11	8.5	1.59	0.8	61	16	.126	.078	38.2	3,800	325	600	500	475	87.5
" 12	8.5	1.51	0.9	71	18	2.8	1.4	50.0	1,900	600	140	250	325	82.9
" 13	9.0	1.48	1.1	65	16				2,200	180	260	220	220	90.0
" 14	8.5	1.47	1.1	86	10	.102	.064	37.3	2,400	240	180	300	240	90.0
" 15	9.0	1.51	1.1	39	6	2.3	1.3	43.4	2,300	275	275	500	350	84.8
" 16	10.0	1.47	1.1	43	4				3,500	250	300	....	275	92.1
" 17	13.0	1.49	1.2	34	3	....	....	....	2,700	....	....	150	150	94.5
" 18	13.0	1.48	1.2	23	3	.086	.062	27.8	4,400	170	400	350	300	93.2
" 19	13.0	1.53	1.2	26	3	1.5	1.2	20.0	3,700	260	400	240	300	91.9
" 20	11.5	1.53	1.3	30	3				5,800	325	190	250	250	95.7
" 21	11.5	1.52	1.3	30	3	.080	.054	32.5	5,900	375	400	220	325	94.5
" 22	12.0	1.54	1.3	33	3	1.6	1.0	37.5	5,700	160	190	130	160	97.2
" 23	13.0	1.56	1.3	28	3				6,300	180	275	....	230	96.4
" 24	12.5	1.55	1.3	25	3	.... ..	....	....	6,100	....	....	130	130	97.9
" 25	12.0	1.59	1.4	31	3	.102	.054	47.1	7,700	160	110	190	150	98.0
" 26	13.0	1.51	1.6	27	4	2.1	1.1	47.6	5,300	170	150	120	140	97.4
" 27	11.5	1.60	1.7	25	3				12,200	210	325	140	220	98.2
" 28	12.0	1.52	2.0	17	3	.124	.062	50.0	9,600	250	180	170	200	97.9
" 29	12.0	1.54	2 1	28	2	2.3	1.3	43.5	6,000	190	100	200	160	97.3
" 30	13.0	1 54	2.3	9	2				4,100	100	120	....	110	97.3
May 1	14.0	1.24	3.0	37	3	.....	....	....	8,900	....	....	135	135	98.5
" 2	15.5	1.76	3.6	37	3	.136	.064	52.9	4,500	170	160	210	180	96.0
" 3	16.0	1.66	3.9	80	5	3.2	1.4	56.3	6,200	80	170	160	140	97.7
" 4	15.5	1.62	4.1	38	5				3,300	180	110	150	150	95.5
" 5	15.0	1.55	4.7	21	5	.118	.062	47.6	2,100	120	90	....	100	95.2
" 6	14.0	1.51	5.2	19	5	2.8	1.7	39.3	2,900	80	70	80	75	97.4
" 7	11.0	1.52	6.3	23	5				1,900	65	85	....	75	96.0
" 8	11 0	1.53	7.5	30	5	.....	....	....	2,700	....	....	32	32	98.8

* Closed inlet July 25, 4:30 P. M.; closed outlet July 26, 4:45 P. M. Opened inlet, after scraping, July 27, 3:10 P. M.; opened outlet, July 27, 9:10 P. M.

Daily Record of the Operation and Efficiency of Filter No. 11.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
May	9	12.0	1.49	7.8	34	5	.196	.080	59.2	2,300	65	55	110	75	96.7
"	10	13.0	1.56	8.3	129	5	3.7	1.7	54.1	15,300	120	160	230	170	98.9
"	11	14.0	1.56	*	82	8				12,200	200	300	210	240	98.0
"	12	14.0	1.40	....	68	9	.152	.082	46.1	8,000	240	120	90	150	98.1
"	13	14.0	1.20	0.1	52	9	3.5	2.0	42.8	4,300	....	150	230	190	95.6
"	14	15.0	0.82	0.1	41	8				3,100	....	....	....	190	93.9
"	15	16.0	1.57	0.1	53	7	.....	....	....	4,000	....	....	196	200	95.0
"	16	17.0	1.54	0.1	68	7	.162	.070	56.8	4,500	130	210	600	325	92.8
"	17	17.5	1.51	0.2	36	6	3.2	1.3	59.4	3,000	350	240	210	275	90.8
"	18	17.0	1.51	0.2	62	5				2,000	110	120	300	180	91.0
"	19	19.0	1.60	0.2	53	4				2,600	120	95	80	100	96.2
"	20	20.0	1.53	0.2	50	4	.116	.072	38.0	1,900	75	110	100	95	95.0
"	21	20.0	1.54	0.2	51	3	2.5	1.3	48.0	2,000	85	55	....	70	96.5
"	22	20.0	1.53	0.2	43	4	.....	....	....	1,500	....	....	50	50	96.7
"	23	20.0	1.50	0.2	111	5				2,500	44	85	95	75	97.0
"	24	20.0	1.55	0.2	136	7	.208	.098	52.9	2,100	60	75	90	75	96.4
"	25	20.0	1.55	0.2	95	13	3.7	1.7	54.1	2,400	110	100	90	100	95.8
"	26	20.0	1.55	0.2	73	13				2,200	110	100	120	110	95.0
"	27	20.0	1.54	0.3	64	9	.138	.072	47.8	2,400	130	95	80	100	95.8
"	28	22.0	1.53	0.3	50	8	3.0	1.6	46.7	1,900	120	120	....	120	93.7
"	29	22.0	1.59	0.3	82	8	.....	....	....	2,900	....	....	100	100	96.5
"	30	22.0	1.57	0.3	62	8	.....	....	....	2,600	....	....	120	120	95.7
"	31	22.0	1.57	0.3	51	9	.152	.072	52.6	1,500	75	100	....	85	94.3
June	1	21.0	1.56	0.3	57	9	2.8	1.6	42.9	1,200	....	....	100	100	91.7
"	2	22.0	1.55	0.3	40	8				1,100	46	55	85	60	94.5
"	3	22.0	1.51	0.3	51	6	.132	.068	48.5	1,300	60	46	48	50	96.0
"	4	22.0	1.52	0.3	41	4	2.7	1.7	37.0	800	34	70	....	50	93.8
"	5	23.0	1.55	0.3	30	4				900	....	....	36	36	96.0
"	6	23.0	1.58	0.3	38	3	.130	.068	47.7	800	32	49	36	39	95.1
"	7	23.0	1.53	0.3	45	5	2.7	1.3	51.9	700	44	39	25	36	94.9
"	8	24.0	1.52	0.3	38	4				600	26	22	22	23	96.2
"	9	24.0	1.52	0.3	27	4	.112	.074	33.9	800	27	23	17	22	97.2
"	10	25.0	1.54	0.3	16	2	2.3	1.3	43.5	700	24	20	18	21	97.0
"	11	25.0	1.53	0.3	16	2				800	21	30	....	26	96.8
"	12	25.0	1.52	0.3	15	2	.116	.062	46.5	700	....	....	50	50	92.9
"	13	26.0	1.52	0.4	14	1	2.3	1.2	47.9	600	27	29	90	49	91.8
"	14	26.0	1.61	0.5	17	1				1,000	47	39	60	49	95.1
"	15	26.0	1.58	0.6	15	1	.116	.070	39.7	800	65	42	29	45	94.4
"	16	24.0	1.56	0.6	12	1	1.7	0.9	47.1	400	34	28	60	41	89.8
"	17	24.0	1.55	0.7	10	1				200	31	25	30	29	85.5
"	18	25.0	1.54	0.7	12	1	.104	.060	42.3	250	29	35	....	32	87.2
"	19	25.0	1.56	0.8	13	1	1.8	0.9	50.0	200	....	....	29	29	85.5
"	20	25.0	1.57	0.8	12	1				100	29	35	17	27	73.0
"	21	25.0	1.54	0.8	10	1*	.090	.060	33.3	150	24	23	20	22	85.3
"	22	23.0	1.54	0.8	8	0	1.5	0.9	40.0	95	20	19	19	19	80.0
"	23	23.0	1.56	0.8	8	0				110	18	33	15	22	80.0
"	24	24.0	1.55	0.9	7	0	.090	.058	35.6	190	22	25	31	26	86.3
"	25	24.0	1.49	0.9	6	2	1.7	1.2	29.4	250	28	29	....	28	88.8
"	26	24.0	1.54	1.0	45	2				4,400	....	....	80	80	98.2
"	27	25.0	1.54	0.8	56	3	.148	.064	56.8	2,400	32	85	42	55	97.7
"	28	25.0	1.54	0.8	67	1	2.5	1.2	52.0	1,000	38	65	31	44	95.6
"	29	25.0	1.65	0.6	45	2				1,500	26	31	26	28	98.1
"	30	25.0	1.61	0.6	57	2	.112	.062	44.6	1,700	65	37	24	42	97.5
July	1	26.0	1.58	0.5	69	2	2.3	1.4	39.2	1,200	24	21	70	38	96.8
"	2	26.0	1.55	0.5	134	2				2,100	65	65	....	65	96.9
"	3	26.0	1.60	0.4	111	3	.182	.066	64.3	1,500	....	....	110	110	92.7
"	4	26.0	1.58	0.4	88	3	3.3	1.7	48.5	1,200	210	....	200	200	83.3
"	5	26.0	1.57	0.3	68	4				1,500	200	110	210	170	88.7
"	6	26.0	1.54	0.4	53	5	.128	.076	40.7	2,500	110	100	130	110	95.6
"	7	27.0	1.58	0.3	37	4	2.7	1.4	48.2	3,200	85	80	42	70	97.8

* Closed inlet May 12, 4:30 P. M.; closed outlet May 14, 8 P. M. Opened inlet, after scraping, May 14, 3:30 P. M.; opened outlet May 14, 9:20 P. M.

Daily Record of the Operation and Efficiency of Filter No. 11.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
July 8	27.0	1.57	*	23	4	.134	.080	40.3	550	120	50	100	90	83.6
" 9	27.0	0.65	0.1	59	3	2.6	1.5	42.3	650	95	....	....	425	85.4
" 10	25.0	1.55	0.1	94	3				325	....	....	1,400	1,400	—330.8
" 11	25.0	1.57	0.1	33	3	.126	.064	49.2	1,400	950	85	225	425	70.0
" 12	24.0	1.56	0.1	36	3	2.3	1.4	39.2	1,200	120	150	230	170	85.8
" 13	24.0	1.57	0.1	38	5				1,500	150	160	80	130	91.3
" 14	24.0	1.56	0.1	28	3	.108	.070	35.2	650	95	42	90	75	88.5
" 15	25.0	1.56	0.1	22	2	2.1	1.3	38.1	600	50	80	85	70	88.3
" 16	26.0	1.61	0.1	16	3				550	75	75	....	75	86.4
" 17	26.0	1.53	0.1	13	3	.114	.062	45.6	950	....	....	60	60	93.7
" 18	26.0	1.58	0.1	16	3	2.1	1.2	42.9	450	60	48	36	47	89.6
" 19	26.0	1.52	0.1	18	2				550	50	35	29	38	93.1
" 20	27.0	1.57	0.1	8	1	.110	.060	45.4	3,200	15	32	65	37	98.8
" 21	27.0	1.54	0.1	16	2	2.2	1.1	50.0	1,100	50	40	60	50	95.0
" 22	27.0	1.55	0.1	23	1				850	27	27	26	27	96.8
" 23	27.0	1.52	0.2	78	1	.188	.062	67.0	4,800	35	19	....	27	99.4
" 24	27.0	1.53	0.1	133	2	3.1	1.3	58.1	8,400	....	....	22	22	99.7
" 25	28.0	1.56	0.2	187	1				5,500	26	18	19	21	99.6
" 26	27.0	1.56	0.2	113	3	.168	.080	52.4	3,300	19	16	24	20	99.4
" 27	28.0	1.51	0.2	90	4	3.0	1.4	53.3	3,600	26	30	37	31	99.1
" 28	28.0	1.57	0.2	66	3				2,500	35	29	22	29	98.8
" 29	27.0	1.58	0.2	70	4	.176	.074	58.0	8,000	28	23	48	33	99.6
" 30	27.0	1.55	0.2	131	7	3.1	1.5	51.6	3,300	45	38	....	42	98.7
" 31	27.0	1.55	0.2	192	8				2,200	....	....	....	....	....

* Closed inlet July 8, 12:15 P. M.; closed outlet July 9, 9:15 A. M. Opened inlet, after scraping, July 9, 2:30 P. M.; opened outlet July 10, 12:25 A. M.

Daily Record of the Operation and Efficiency of Filter No. 12.

March 28	11.0	1.58	0.2	169	....				....	....	1,900	....	1,900	....
" 29	11.0	1.17	0.2	140	40	.238	.138	42.0	16,600	3,000	....	6,000	4,500	72.9
" 30	10.5	1.53	0.2	115	35	5.0	2.8	44.0	11,300	5,800	lost	2,000	3,900	65.2
" 31	9.0	1.53	0.3	171	35				5,700	2,200	2,200	2,100	2,200	61.4
April 1	9.0	1.52	0.3	86	40	.226	.144	36.2	9,500	3,200	1,400	2,200	2,300	75.8
" 2	9.5	1.56	0.3	83	35	4.7	3.2	31.9	4,700	2,900	2,700	....	2,800	40.5
" 3	9.5	1.58	0.3	75	30				6,100	....	....	2,100	2,100	65.6
" 4	9.0	1.59	0.3	80	25	.166	.134	19.3	4,100	2,800	2,400	3,000	2,700	34.2
" 5	7.0	1.58	0.3	75	20	3.5	2.5	28.6	3,600	1,700	1,700	1,800	1,700	52.8
" 6	6.5	1.52	0.4	40	15				3,500	1,600	1,300	900	1,300	62.9
" 7	6.0	1.53	0.4	52	16	.165	.080	51.5	3,400	1,100	1,100	425	900	73.5
" 8	7.0	1.52	0.5	90	18	3.4	2.0	41.2	2,700	600	700	850	700	74.0
" 9	8.0	1.52	0.5	50	20				2,100	800	600	....	700	66.7
" 10	8.0	1.53	0.7	92	24				2,800	....	....	....	....	....
" 11	8.5	1.61	0.7	61	26	.126	.080	36.6	3,800	300	210	240	250	93.4
" 12	8.5	1.51	0.8	71	28	2.8	1.4	50.0	1,900	210	200	120	180	90.5
" 13	9.0	1.51	0.8	65	24				2,200	180	210	275	220	90.0
" 14	8.5	1.54	1.0	86	18	.102	.072	29.5	2,400	180	160	220	190	92 1
" 15	9.0	1.54	1.0	39	12	2.3	1 2	47.8	2,300	160	210	220	200	91.3
" 16	10.0	1.54	1.0	43	6				3,500	375	200	....	300	91.4
" 17	13.0	1 51	1.0	34	4				2,700	....	....	275	275	89 8
" 18	13.0	1.54	1.1	23	4	.086	.062	27.8	4,400	275	180	210	220	95.0
" 19	13.0	1.56	1.1	26	4	1.5	1.2	20.0	3,700	180	180	150	170	95.4
" 20	11.5	1.56	1.1	30	4				5,800	120	120	150	130	97 8
" 21	11.5	1.55	1.1	30	3	.080	.054	32.5	5,900	190	180	120	160	97.3
" 22	12.0	1.54	1 2	33	3	1.6	1.1	31.2	5,700	120	220	325	220	96.1
" 23	13.0	1.53	1.3	28	4				6,300	220	120	....	170	97.3
" 24	12.5	1.52	1.4	25	4				6,100	....	....	120	120	98.0

Daily Record of the Operation and Efficiency of Filter No. 12.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
April 25	12.0	1.54	1.4	31	4	.102	.056	45.1	7,700	110	130	160	130	98.3
" 26	13.0	1.57	1.5	27	4	2.1	1.1	47.6	5,300	80	120	150	120	97.7
" 27	11.5	1.55	1.8	25	4				12,200	120	200	150	160	98.7
" 28	12.0	1.58	1.8	17	4	.124	.064	48.4	9,600	190	180	160	180	98.1
" 29	12.0	1.56	2.1	28	3	2.3	1.2	47.8	6,000	130	110	180	140	97.7
" 30	13.0	1.56	2.3	9	4				4,100	120	130	....	120	97.1
May 1	14.0	1.55	2.4	37	3	.....	....	....	8,900	....	....	120	120	98.6
" 2	15.5	1.54	2.8	37	3	.136	.074	45.6	4,500	150	160	130	150	96.7
" 3	16.0	1.54	3.2	80	5	3.2	1.6	50.0	6,200	110	130	120	120	98.1
" 4	15.5	1.51	3.4	38	5				3,300	170	90	250	170	94.8
" 5	15.0	1.58	3.5	21	5	.118	.070	40.8	2,100	130	90	70	95	95.5
" 6	14.0	1.77	3.9	19	6	2.8	1.8	35.7	2,900	70	85	85	80	97.2
" 7	11.0	1.53	4.5	23	5				1,900	75	70	....	70	96.3
" 8	11.0	1.51	4.9	30	5	.....	....	....	2,700	....	....	85	85	96.9
" 9	12.0	1.51	5.5	24	5	.196	.082	58.2	2,300	90	140	100	110	95.2
" 10	13.0	1.54	6.0	129	5	3.7	1.9	48.7	15,300	170	400	200	250	98.4
" 11	14.0	1.55	6.1	82	8				12,200	170	250	170	200	98.4
" 12	14.0	1.51	4.9	68	9	.152	.086	43.4	8,000	150	275	200	210	97.4
" 13	14.0	1.44	3.4	52	13	3.5	1.9	45.7	4,300	160	110	160	140	96.7
" 14	15.0	1.61	4.4	41	13				3,100	140	110	....	120	96.1
" 15	16.0	1.60	....	53	10	.....	....	....	4,000	....	....	250	250	93.8
" 16	17.0	0.98	*	68	7	.162	.074	54.4	4,500	110	130	....	120	97.3
" 17	17.5	0.25	0.1	36	6	3.2	1.4	56.2	3,000	....	....	140	120	96.0
" 18	17.0	1.51	0.1	62	4				2,000	90	80	325	160	92.0
" 19	19.0	1.60	0.1	53	4	.116	.076	34.5	2,600	90	120	120	110	95.8
" 20	20.0	1.51	0.1	50	4	2.5	1.5	40.0	1,900	80	46	110	80	95.8
" 21	20.0	1.54	0.1	51	3				2,000	32	48	....	40	98.0
" 22	20.0	1.53	0.1	43	8	.....	....	....	1,500	....	....	60	60	96.0
" 23	20.0	1.48	0.1	111	9	.208	.100	51.9	2,500	70	44	80	65	97.4
" 24	20.0	1.60	0.1	136	23	3.7	1.8	51.4	2,100	65	75	120	85	96.0
" 25	20.0	1.52	0.1	95	25				2,400	130	80	65	90	96.2
" 26	20.0	1.57	0.1	73	25	.138	.072	47.8	2,200	90	110	85	95	95.7
" 27	20.0	1.54	0.2	64	13	3.0	1.8	40.0	2,400	90	75	275	150	93.7
" 28	22.0	1.68	0.2	50	11				1,900	110	80	....	95	95.0
" 29	22.0	1.56	0.2	82	20	.....	....	....	2,900	....	....	85	85	97.1
" 30	22.0	1.55	0.2	62	16	.....	....	....	3,600	....	....	110	110	96.9
" 31	22.0	1.56	0.2	51	18	.152	.076	50.0	1,500	65	65	....	65	95.7
						2.8	1.8	35.7						

* Closed inlet May 15, 4 P. M.; closed outlet May 16, 5 P. M. Opened inlet, after scraping, May 17, 4 P. M.; opened outlet May 17, 8:25 P. M.

Daily Record of the Operation and Efficiency of Filter No. 13.

March 28	11.0	2.65	0.4	169	....	.....	....	....	....	....	3,600	....	3,600	
" 29	11.0	1.47	0.4	140	25	.238	.094	60.5	....	....	....	6,600	5,000	69.9
" 30	10.5	2.50	0.4	115	20	5.0	2.3	54.0	16,600	3,400	....	....	3,400	79.6
" 31	9.0	2.51	0.5	171	20				11,200	lost	2,800	2,000	2,400	78.6
April 1	9.0	2.50	0.6	86	25	.226	.136	42.6	5,700	1,900	2,200	2,200	2,100	63.2
" 2	9.5	2.61	0.6	83	20	4.7	2.7	39.9	9,500	1,700	1,500	900	1,400	85.3
" 3	9.5	2.63	0.6	75	15	.....	....	....	4,700	1,200	1,000	....	1,100	76.6
" 4	9.0	2.67	0.7	80	14				6,100	....	....	550	550	91.0
" 5	7.0	2.57	0.7	75	12	.166	.104	31.4	4,100	1,100	850	900	950	76.8
" 6	6.5	2.55	0.9	40	10	3.5	2.4	37.4	3,600	550	500	800	600	83.3
									3,500	700	1,000	325	700	80.0

Daily Record of the Operation and Efficiency of Filter No. 13

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
April	7	6.0	2.88	1.1	52	12	.165	.060	52.9	3,400	425	275	450	375	89.0
"	8	7.0	2.62	1.2	90	14	3.4	1.6	63.6	2,700	475	250	375	375	86.1
"	9	8.0	2.58	1.3	50	16				2,100	230	325	....	275	86.9
"	10	8.0	2.55	1.7	92	14	.....	....	....	2,800	....	....	300	300	89.3
"	11	8.5	2.50	2.1	61	12				3,800	200	230	210	210	94.5
"	12	8.5	2.54	2.6	71	10	.126	.064	49.3	1,900	190	55	110	120	93.7
"	13	9.0	2.51	3.2	65	8	2.8	1.1	60.7	2,200	90	90	160	110	95.0
"	14	8.5	2.54	3.5	86	6				2,100	140	85	95	110	95.4
"	15	9.0	2.61	3.5	39	5	.102	.054	47.1	2,300	80	95	240	140	93.9
"	16	10.0	2.57	3.7	43	4	2.3	1.2	47.8	3,500	160	150	....	160	95.4
"	17	13.0	2.57	3.9	34	3	.....	....	....	2,700	....	....	90	90	96.7
"	18	13.0	2.60	4.1	23	3				4,400	240	150	150	180	95.9
"	19	13.0	2.59	4.5	26	3	.066	.054	37.2	3,700	170	160	400	240	93.5
"	20	11.5	2.62	4.8	30	3	1.5	1.0	33.3	5,800	275	230	140	220	96.2
"	21	11.5	2.61	5.0	30	3				5,900	190	180	100	160	97.3
"	22	12.0	2.55	5.2	33	3	.080	.056	30.0	5,700	100	160	160	140	97.5
"	23	13.0	2.65	5.5	28	3	1.6	1.0	37.5	6,300	150	220	....	180	97.1
"	24	12.5	2.51	5.8	25	4	.....	....	....	6,100	....	....	170	170	97.2
"	25	12.0	2.50	3.5	31	3				7,700	100	275	160	180	97.7
"	26	13.0	2.61	4.6	27	4	.102	.054	47.1	5,300	180	190	210	190	96.4
"	27	11.5	2.65	5.1	25	3	2.1	1.1	47.6	12,200	425	550	475	475	96.1
"	28	12.0	2.57	5.7	17	3				9,600	600	650	300	500	94.8
"	29	12.0	2.52	6.3	28	2	.124	.064	48.4	6,000	750	250	550	500	91.7
"	30	13.0	2.60	7.1	9	3	2.3	1.2	47.8	4,100	580	400	....	450	89.0
May	1	14.0	2.60	7.5	37	3	.....	....	....	8,900	....	....	375	375	95.8
"	2	15.5	2.35	....	37	3				4,500	400	250	250	300	93.3
"	3	16.0	2.43	*	80	3	.136	.056	58.8	6,200	180	220	350	250	96.0
"	4	15.5	0.94	0.3	38	3	3.2	1.5	53.2	3,300	190	....	200	190	94.2
"	5	15.0	2.65	0.3	21	3				2,100	220	100	80	130	93 8
"	6	14.0	2.60	0 3	19	4	.118	.060	49.2	2,900	85	60	70	70	97.6
"	7	11.0	2.58	0.3	23	4	2.8	1.3	53.5	1,900	70	120	....	95	95.0
"	8	11.0	2.56	0.3	30	4	.....	....	....	2,700	....	....	70	70	97.4
"	9	12 0	2.65	0.4	24	4				2,300	55	70	110	80	96.5
"	10	13.0	2.69	0.4	129	5	.196	.074	62.3	15,300	130	240	200	190	98.8
"	11	14 0	2 67	0.4	82	7	3.7	1.6	56.8	12,200	140	180	110	140	98.8
"	12	14.0	2.64	0.4	68	6				8,000	120	85	140	120	98.5
"	13	14.0	2.61	0 5	52	8	.152	.074	51.3	4,300	70	70	50	65	98 5
"	14	15.0	2.58	0.5	41	7	3.5	1.7	51.4	3,100	95	65	....	80	97.4
"	15	16.0	2.65	0.5	53	6	.....	....	....	4,000	....	....	65	60	98.5
"	16	17.0	2.59	0.5	68	5				4,500	80	55	43	60	98.7
"	17	17.5	2.66	0.7	36	5	.162	.066	59.3	3,000	39	60	39	46	98.5
"	18	17 0	2.63	0.8	62	4	3.2	1.4	56.2	2,000	39	36	100	60	97.0
"	19	19.0	2.67	0.9	53	3				2,600	60	55	55	55	97.9
"	20	20.0	2.69	1.0	50	3	.116	.068	41.4	1,900	41	60	31	44	97.7
"	21	20.0	2.71	1.0	51	2	2.5	1.2	52.0	2,000	38	44	....	41	98.0
"	22	20.0	2.51	1.2	43	3	.....	....	....	1,500	....	....	80	80	94.7
"	23	20.0	2.74	1.3	111	4				2,500	45	48	50	48	98.1
"	24	20 0	2.65	1.4	136	8	.208	.090	56.8	2,100	45	65	100	70	96.7
"	25	20.0	2.59	1 6	95	8	3.7	1.6	56.8	2,400	60	55	55	55	97.7
"	26	20.0	2 59	1.9	73	8				2,200	70	110	50	75	96.6
"	27	20.0	2.62	2.0	64	6	.138	.062	55.1	2,100	70	55	60	60	97.5
"	28	22.0	2.66	2.2	50	6	3.0	1.5	50.0	1,900	85	85	....	85	95.5
"	29	22.0	2.63	2.4	82	6	.....	....	....	2,900	....	....	70	70	97 6
"	30	22.0	2.59	2.5	62	6	.....	....	....	3,600	....	....	49	49	98 6
"	31	22.0	2.64	2 7	51	7				1,500	40	50	46	45	97.0
June	1	21.0	2.74	2.7	57	8	.152	.068	55.3	1,200	....	....	55	55	95.4
"	2	22.0	2.63	2.7	40	6	2.8	1.5	46.4	1,100	49	43	50	48	95.6
"	3	22.0	2.64	2.8	51	6	.132	.062	53.0	1,300	50	44	38	44	96.6
"	4	22.0	2.61	2 9	41	3	2.7	1.5	44.4	800	38	40	....	39	95.2

* Closed inlet May 3, 8:20 A. M.; closed outlet May 4, 11 A. M. Opened inlet, after scraping, May 4, 8 P. M.; opened outlet May 4, 11:30 P. M.

Daily Record of the Operation and Efficiency of Filter No. 13.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
June 5	23.0	2.53	3.2	30	2	.130	.062	52.3	900	....	....	34	34	96.2
" 6	23.0	2.55	*	38	2	2.7	1.2	55.6	800	31	22	12	22	97.2
" 7	23.0	1.50	0.2	45	5				700	23	....	18	20	97.1
" 8	24.0	2.61	0.2	38	4	.112	.064	42.9	600	22	25	22	23	96.2
" 9	24.0	2.63	0.2	27	2	2.3	1.2	47.9	800	36	35	22	31	96.1
" 10	25.0	2.64	0.2	16	2				700	26	19	26	24	96.6
" 11	25.0	2.63	0.2	16	1	.116	.056	51.7	800	26	46	....	36	95.5
" 12	25.0	2.62	0.2	15	2	2.3	1.0	56.5	700	....	....	25	25	96.4
" 13	26.0	2.62	0.3	14	1				600	21	17	28	22	96.3
" 14	26.0	2.63	0.3	17	1	.116	.062	46.6	1,000	21	43	14	26	97.4
" 15	26.0	2.70	0.3	15	1	1.7	1.0	41.2	800	15	11	12	13	98.4
" 16	24.0	2.62	0.4	12	1				400	17	5	32	18	95.5
" 17	24.0	2.65	0.4	10	1	.104	.056	46.1	200	15	10	12	12	94.0
" 18	25.0	2.65	0.4	12	1	1.8	0.8	55.6	250	7	7	....	7	97.2
" 19	25.0	2.65	0.4	13	1				200	....	....	9	9	95.5
" 20	25.0	2.68	0.4	12	1	.090	.054	40.0	100	11	13	12	12	88.0
" 21	25.0	2.65	0.5	10	1	1.5	0.8	46.7	150	15	15	8	13	91.3
" 22	23.0	2.62	0.5	8	0				95	2	15	2	6	93.7
" 23	23.0	2.64	0.5	8	0	.090	.050	44.4	110	5	12	21	13	88.2
" 24	24.0	2.60	0.5	7	0	1.7	0.9	47.1	190	22	19	20	20	89.5
" 25	24.0	2.58	0.8	6	2				250	14	8	....	11	95.6
" 26	24.0	2.63	1.3	45	2	.148	.058	60.8	4,400	....	....	14	14	99.7
" 27	25.0	2.64	1.3	56	2	2.5	1.2	52.0	2,400	15	7	10	11	99.5
" 28	25.0	2.60	2.4	67	1				1,000	9	7	9	8	99.2
" 29	25.0	2.64	2.8	45	1	.112	.058	48.2	1,500	8	7	8	8	99.5
" 30	25.0	2.64	3.2	57	2	2.3	1.1	52.2	1,700	10	8	12	10	99.4
July 1	26.0	2.65	3.8	69	2				1,200	18	9	12	13	98.9
" 2	26.0	2.10	†	134	2	.182	.062	65.9	2,100	16	23	....	46	97.8
" 3	26.0	2.26	0.2	111	2	3.3	1.5	54.5	1,500	....	....	90	90	94.0
" 4	26.0	2.60	0.2	88	2				1,200	75	....	19	47	96.1
" 5	26.0	2.63	0.3	68	2	.128	.064	50.0	1,500	44	48	21	38	97.5
" 6	26.0	2.64	0.3	53	3	2.7	1.4	48.2	2,500	28	23	19	23	99.1
" 7	27.0	2.61	0.3	37	3				3,200	27	15	12	18	99.4
" 8	27.0	2.65	0.3	23	2	.134	.070	47.7	550	21	13	10	15	97.3
" 9	27.0	2.59	0.3	59	3	2.6	1.5	42.3	650	8	14	....	11	98.3
" 10	25.0	2.65	0.4	94	2				325	....	....	24	24	92.6
" 11	25.0	2.63	0.4	33	3	.126	.058	54.0	1,400	4	9	11	8	99.4
" 12	24.0	2.61	0.4	36	2	2.3	1.3	43.5	1,200	8	13	8	10	99.2
" 13	24.0	2.60	0.4	38	3				1,500	11	13	3	9	99.4
" 14	24.0	2.59	0.4	28	2	.108	.064	40.8	650	12	7	9	9	98.6
" 15	25.0	2.62	0.4	22	2	2.1	1.2	42.9	600	11	14	12	12	98.0
" 16	26.0	2.71	0.4	16	2				550	11	17	....	14	97.5
" 17	26.0	2.58	0.4	13	2	.114	.058	49.1	950	....	....	9	9	99.1
" 18	26.0	2.60	0.4	16	2	2.1	1.2	42.9	450	15	12	9	12	97.3
" 19	26.0	2.59	0.4	18	2				550	14	10	13	12	97.8
" 20	27.0	2.64	0.5	8	1	.110	.056	49.0	3,200	12	8	9	10	99.7
" 21	27.0	2.58	0.5	16	1	2.2	1.1	50.0	1,100	7	4	10	7	99.4
" 22	27.0	2.57	0.5	23	1				850	13	8	12	11	98.7
" 23	27.0	2.63	0.8	78	2	.188	.058	69.1	4,800	11	8	....	10	99.8
" 24	27.0	2.59	1.0	133	1	3.1	1.0	67.7	8,400	....	....	9	9	99.9
" 25	28.0	2.64	1.0	187	1				5,500	26	23	12	20	99.6
" 26	27.0	2.64	1.0	113	2	.168	.072	57.2	3,300	15	13	10	13	99.6
" 27	28.0	2.62	1.0	90	2	3.0	1.2	60.0	3,600	13	10	8	10	99.7
" 28	28.0	2.61	1.1	66	3				2,500	15	9	11	12	99.5
" 29	27.0	2.57	0.9	70	4	.176	.066	62.5	8,000	8	9	15	11	99.9
" 30	27.0	2.65	1.2	131	5	3.1	1.3	58.1	3,300	16	20	....	18	99.5
" 31	27.0	2.62	1.4	192	6				2,200	....	....	25	25	98.9

* Closed inlet June 6, 4 P. M.; closed outlet June 7, 9 A. M. Opened inlet, after scraping. June 7, 4 P. M.; opened outlet, June 7, 8:40 P. M.

† Closed inlet July 2, 3:30 A. M.; closed outlet July 2, 10 A. M. Opened inlet, after scraping. July 2, 11:15 P. M.; opened outlet July 3, 3:25 A. M.

Daily Record of the Operation and Efficiency of Filter No. 13.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided. Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
Aug. 1	26.0	2.65	1.7	315	6	.224	.066	70.5	5,400	11	16	15	14	99.7
" 2	26.0	2.47	*	185	7	3.5	1.2	65.7	1,100	16	28	20	21	98.1
" 3	26.0	1.06	....	76	6				3,200	15	....	....	15	99.5
" 4	26.0	2.12	0.3	189	3				2,300	17	28	23	23	99.0
" 5	26.0	2.62	0.3	140	6	.176	.072	59.1	1,600	26	26	43	32	98.0
" 6	25.0	2.61	0.4	91	7	3.3	1.3	60.6	1,700	37	47	....	42	97.5
" 7	25.0	2.60	0.4	87	5				2,500	....	....	32	32	98.7
" 8	26.0	2.62	0.4	100	5				4,100	35	15	41	30	99.3
" 9	25.0	2.66	0.5	113	6				4,200	29	29	37	32	99.2
" 10	25.0	2.62	0.5	176	7	.190	.068	64.2	4,400	25	20	38	28	99.4
" 11	25.0	2.59	....	207	7	3.2	1.3	59.4	3,800	23	18	17	19	99.5
" 12	25.0	0.17	....	266	....				3,600	....	....	....	....	....
" 13	25.0	0.94	0.3	280	....				4,800	....	19	....	19	99.6
" 14	25.0	1.57	0.2	212	10	.234	.088	62.4	6,100	....	....	40	40	99.3
" 15	24.0	1.48	0.3	237	20	5.0	1.9	62.0	3,200	50	60	65	60	98.1
" 16	25.0	2.22	0.5	241	20				2,300	45	75	100	75	96.7
" 17	25.0	2.63	0.6	199	30				3,100	75	70	110	85	97.3
" 18	25.0	2.61	0.7	130	30	.180	.102	43.4	1,600	70	65	50	60	96.2
" 19	24.0	2.63	0.7	100	25	4.4	2.5	43.2	1,700	65	50	60	60	96.5
" 20	24.0	2.56	0.9	143	20				5,100	28	36	....	32	99.4
" 21	25.0	2.56	1.0	186	10				4,800	....	....	19	19	99.6
" 22	25.0	2.61	1.2	137	13	.186	.096	48.4	3,800	27	41	25	31	99.2
" 23	26.0	2.59	1.3	139	13	4.1	1.8	56.1	4,800	20	24	27	24	99.5
" 24	25.0	2.67	1.7	113	15				3,400	35	33	26	31	99.1
" 25	26.0	2.57	2.0	80	13				1,400	19	21	33	24	98.3
" 26	25.0	1.72	....	75	14	.155	.088	43.2	1,000	29	39	....	34	96.6
" 27	25.5	....	†	57	....	3.7	1.7	54.0	1,000	....	....	....	....	....
" 28	24.0	0.37	0.3	55	6				1,600	....	....	28	40	97.5
" 29	24.5	1.78	0.4	84	5				1,400	19	20	37	25	98.2
" 30	25.5	2.42	0.5	115	9	.166	.084	49.5	1,500	55	65	29	46	96.9
" 31	25.5	2.83	0.6	93	10	3.5	1.7	51.5	1,500	33	24	20	26	98.3
Sept. 1	26.0	2.68	0.6	66	5				2,300	16	26	22	21	99.1
" 2	26.0	2.64	0.6	57	7				2,200	21	18	19	19	99.1
" 3	27.0	2.59	0.7	53	7	.165	.084	49.2	1,700	50	21	....	36	97.9
" 4	28.0	2.63	0.8	38	6	3.9	1.7	56.4	3,300	....	....	24	24	92.7
" 5	25.0	2.57	0.9	33	6				1,500	16	....	26	21	98.6
" 6	27.0	2.72	0.9	20	6				1,000	21	30	19	23	97.7
" 7	25.0	2.64	1.1	12	5	.138	.090	34.9	450	12	26	27	22	95.1
" 8	23.0	2.61	1.3	10	7	3.3	1.9	42.4	600	22	20	16	19	96.8
" 9	23.0	2.59	1.6	9	4				850	9	16	18	14	98.4
" 10	22.0	2.61	1.8	14	3				1,500	12	19	....	16	98.9
" 11	22.0	0.68	‡	12	....	.130	.082	37.0	1,600	....	....	....	....	....
" 12	21.0	0.88	0.5	7	....	2.8	1.7	39.2	550	....	....	55	85	84.5
" 13	21.0	2.67	0.5	14	2				220	55	20	36	37	83.2
" 14	21.0	2.67	0.5	10	3				275	26	44	35	35	87.3
" 15	22.0	2.68	0.6	12	3	.118	.070	40.7	2,600	50	33	39	41	98.4
" 16	22.0	2.69	0.6	11	5	2.0	1.4	30.0	2,100	33	18	23	25	98.8
" 17	21.0	2.69	0.7	12	1				1,400	17	22	....	20	98.6
" 18	22.0	2.72	0.8	18	2				4,200	....	....	24	24	99.4
" 19	22.0	2.74	0.8	33	2	.114	.068	40.4	2,200	28	37	34	33	98.5
" 20	21.0	2.68	0.9	11	0	2.2	1.3	41.0	1,900	39	23	20	27	98.6
" 21	22.0	2.72	0.9	10	1				1,400	22	21	19	21	98.5
" 22	23.0	2.70	1.0	16	1				1,200	22	21	20	21	98.2
" 23	22.0	2.67	1.0	27	1	.122	.072	41.0	5,000	22	10	14	15	99.7
" 24	23.0	2.66	1.3	30	1	2.1	1.3	38.1	4,200	14	23	....	18	99.6
" 25	22.0	2.63	1.5	15	0				11,900	....	....	13	13	99.9

* Closed inlet August 2, 5:40 P. M.; closed outlet August 3, 10:55 A. M. Opened inlet, after scraping, August 3, 9:30 P. M.; opened outlet, August 4, 2:50 A. M.

† Closed inlet August 11, 9:50 A. M.; closed outlet August 12, 1:45 A. M. Opened inlet, after scraping, August 12, 10:25 A. M.; opened outlet, August 13, 9 A. M.

‡ Closed inlet September 10, 1 P. M.; closed outlet September 11, 6 A. M. Opened inlet, after scraping, September 11, 2:05 P. M.; opened outlet September 12, 4 P. M.

Daily Record of the Operation and Efficiency of Filter No. 13.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
Sept. 26	23.0	2.59	1.6	7	1				2,000	13	9	9	10	99.5
" 27	23.0	2.53	1.9	17	0	.121	.060	50.8	700	10	20	7	13	98.1
" 28	22.0	2.63	2.4	21	0	2.0	1.3	35.0	2,200	8	16	20	15	99.3
" 29	22.0	2.64	3.0	25	0				1,400	21	20	17	19	98.6
" 30	23.0	2.69	3.3	26	1				2,300	17	16	13	15	99.3
Oct. 1	23.0	2.61	3.7	12	1	.120	.066	45.0	1,300	10	12	....	11	99.2
" 2	23.0	1.78	*	9	1	1.9	1.4	26.3	1,000	...	....	....	....	....
" 3	23.5	0.34	0.6	7	1				450	....	....	17	17	96.2
" 4	24.0	2.68	0.5	7	1				2,000	21	39	22	27	98.6
" 5	23.5	2.65	0.5	10	1	.093	.056	39.8	1,000	22	27	32	27	97.3
" 6	23.0	2.37	0.5	11	1	1.7	1.0	41.2	15,300	22	27	24	24	99.8
" 7	21.5	2.66	0.5	14	1				5,300	19	20	14	18	99.7
" 8	21.5	2.97	0.6	15	1				4,400	11	11	....	11	99.8
" 9	21.0	2.65	0.6	10	1	.086	.056	34.9	4,000	....	....	13	13	99.7
" 10	20.0	2.61	0.7	8	0	1.4	1.0	28.6	4,200	16	15	7	13	99.7
" 11	21.0	2.56	0.7	6	0				2,400	15	7	12	11	99.5
" 12	20.0	2.66	0.8	6	0				1,600	13	20	13	15	99.1
" 13	18.0	2.65	0.8	12	1	.094	.060	36.2	1,100	15	15	13	14	98.8
" 14	17.0	2.60	0.9	17	0	1.6	1.0	37.6	1,700	14	34	7	18	98.9
" 15	16.0	2.56	1.0	16	0				1,800	13	6	....	10	99.4
" 16	10.0	2.56	1.2	20	0				1,000	...	8	16	12	98.8
" 17	15.5	2.66	1.3	22	0	.108	.070	35.2	1,800	10	9	8	9	99.5
" 18	14.0	2.63	1.5	10	2	1.9	1.1	42.2	3,100	9	26	11	15	99.5
" 19	13.0	2.63	1.6	8	1				2,100	10	9	13	11	99.5
" 20	13.0	2.63	1.8	10	1				9,600	11	31	14	19	99.8
" 21	14.0	2.62	1.9	11	1	.141	.064	54.6	5,900	14	17	19	17	99.7
" 22	12.0	2.59	2.0	14	0	2.3	1.1	52.2	2,000	9	6	....	8	99.6
" 23	11.0	2.56	2.1	12	0				1,900	9	5	12	9	99.5
" 24	12.0	2.69	2.1	14	0				1,200	15	13	12	13	98.9
" 25	12.0	2.63	2.0	16	0	.106	.058	47.2	700	13	12	9	11	98.4
" 26	12.0	2.63	2.1	12	0	1.8	1.2	33.3	900	9	9	20	13	98.6
" 27	11.0	2.58	2.6	17	0				3,000	6	17	17	13	99.6
" 28	10.0	2.59	3.2	48	1				2,400	9	7	11	9	99.6
" 29	9.0	2.69	3.6	121	0	.154	.070	54.5	5,400	29	22	....	26	99.5
" 30	9.5	2.60	4.0	103	8	3.7	1.5	51.5	5,400	40	37	24	34	99.4
" 31	9.0	1.67	0.8†	78	....				5,300	....	....	75	75	98.6
Nov. 1	8.5	2.57	0.9	71	7				5,500	90	65	85	80	98.5
" 2	9.0	2.80	1.1	75	10	.161	.088	45.4	4,400	65	50	85	65	98.5
" 3	9.0	2.79	1.2	73	10	4.0	2.0	50.0	3,600	70	45	140	85	97.6
" 4	9.0	2.63	1.3	59	12				3,200	160	60	70	100	96.9
" 5	10.5	2.63	1.4	49	7				3,800	55	49	....	50	98.7
" 6	10.5	2.61	1.6	33	7	.143	.088	38.4	2,800	34	45	33	37	98.7
" 7	9.0	2.60	1.6	27	5	3.8	2.5	34.2	2,000	42	41	43	42	97.0
" 8	9.0	2.59	1.8	49	8				2,000	38	29	41	36	98.2
" 9	9.5	2.57	1.9	43	7				6,500	46	48	39	44	99.3
" 10	10.0	2.56	1.9	44	7	.154	.074	51.9	5,900	39	33	32	34	99.4
" 11	8.5	2.58	2.2	47	5	3.6	2.2	38.9	11,800	34	43	44	40	99.7
" 12	7.5	2.56	2.4	76	6				19,400	60	36	...	48	99.8
" 13	7.5	2.55	2.5	134	7				35,500	70	90	130	95	99.7
" 14	8.0	2.51	2.8	108	9	.274	.096	65.0	37,800	180	210	150	180	99.5
" 15	8.0	2.54	3.0	70	10	5.1	2.4	53.0	31,800	110	95	100	100	99.7
" 16	7.0	2.56	3.2	59	10				21,300	140	100	95	110	99.5
" 17	7.0	0.25	‡	113	....				23,000	....	....	....	....	....
" 18	8.0	0.97	0.45	101	....	.212	.092	56.6	25,800	....	50	110	80	99.7
" 19	9.0	2.07	0.8	112	16	5.4	2.6	51.8	18,900	90	....	....	90	99.5
" 20	8.0	2.62	0.9	62	16				8,700	130	140	110	130	98.5

* Closed inlet October 1, 10 P. M.; closed outlet October 2, 5:20 P. M. Opened inlet, after scraping, October 3, 3:50 P. M.; opened outlet October 3, 9:15 P. M.

† Closed inlet October 30, 3 P. M.; closed outlet October 31, 8 A. M. Opened inlet, after scraping, October 31, 3:25 P. M.; opened outlet October 31, 6:05 P. M.

‡ Closed inlet November 16, 9:20 P. M.; closed outlet November 17, 2 A. M. Opened inlet, after scraping, November 17, 1:25 P. M.; opened outlet November 18, 9 A. M.

Daily Record of the Operation and Efficiency of Filter No. 13.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
Nov. 21	8.0	2.50	1.0	51	16				7,300	90	100	95	95	98.7
" 22	8.5	2.53	1.2	41	11	.187	.116	38.0	6,200	85	23	70	59	99.0
" 23	10.5	2.50	1.2	43	10	4.8	3.1	35.4	5,600	75	55	120	80	98.4
" 24	5.0	2.51	1.4	42	10				5,800	....	....	80	80	98.6
" 25	4.0	2.62	1.5	40	5				5,800	60	65	75	65	98.9
" 26	3.0	2.60	1.6	34	7	.123	.084	31.6	3,600	85	65	65	70	98.1
" 27	2.0	2.62	1.7	30	....	8.3	2.2	33.3	3,400	....	90	80	85	97.5
" 28	2.0	2.62	1.8	29	9				3,100	75	75	70	75	97.6
" 29	2.5	2.58	1.9	20	5				4,000	80	70	85	80	98 0
" 30	3.0	2.59	2.0	21	....	.111	.084	24.4	3,800	95	65	65	75	98.0
Dec. 1	8.0	2.58	2.0	19	5	2.8	2.1	25.0	3,100	39	42	43	41	98.7
" 2	2.5	2.57	2.2	20	7				4,800	41	35	70	48	99 0
" 3	2.5	2.56	2.4	16	3				3,800	31	190	....	110	97.1
" 4	4.0	2.56	2 5	22	4	.101	.072	28.7	4,000	38	50	65	50	98.8
" 5	2.5	2.63	2.7	16	4	2.5	1.5	40.0	3,200	....	30	38	34	99.0
" 6	1.5	2.61	2.9	16	3				3,600	37	21	55	38	98.9
" 7	1.0	2 58	3.0	13	4				2,500	33	35	19	29	98.8
" 8	1.0	2.55	3.3	154	3	.212	.068	67.9	30,400	24	250	550	275	99.1
" 9	2.0	2.12	3 8	153	8	4.1	1 8	56.1	70,700	1,100	2,100	....	1,600	97.7
" 10	....	....	*	....	....				....	....	....	....	....	....
" 11	....	....	....	....	....	.....	....	....	....	....	....	....	....	....
" 12	....	....	....	....	....	.....	....	....	....	....	....	....	....	....
" 13	....	....	....	....	....	.....	....	....	28,100	....	....	600	600	97.9
" 14	0.0	1.49†	....	57	....	.....	....	....	17,300	....	350	....	350	98.0
" 15	0.0	0.46†	....	47	....	.....	....	....	16,600	....	....	450	450	97.3
" 16	0.0	2.08†	....	29	11	.....	....	....	15,200	600	...	....	600	96 4
" 17	....	0.00†	....	26	....	.....	....	....	....	....	....	....	....	....
" 18	....	0 00†	....	25	....	.....	....	....	....	....	....	....	....	....
" 19	0.0	0 92†	1.1	18	....				11,100	....	325	400	350	96.9
" 20	0.5	2.64	1.1	100	11	.140	.098	30.0	14,300	700	500	450	550	96.2
" 21	1.0	2.66	1.1	172	8	2.5	1.7	32.0	11,000	600	450	1,700	900	91.8
" 22	1.0	2 61	1.1	163	23				38,800	4,500	11,000	3,800	6,400	83.5
" 23	2.0	2.65	1.6	160	18				49,000	3,600	5,700	1,300	3,500	92.9
24	1.5	2.64	1.8	146	20	.311	.120	61.4	63,200	3,800	3,300	....	3,600	94.3
" 25	1.5	2.62	1.8	100	18	5.1	2.2	56.9	66,700	3,500	2,200	2,800	2,800	95.8
" 26	1.0	2.59	2.0	90	18				27,600	1,400	950	400	900	96.7
" 27	1.0	2.55	2.3	74	18				25,700	650	650	450	600	97.7
" 28	1.0	0.73	....	76	....	.230	.108	53.0	16,400	450	....	....	450	97.3
" 29	0.0	0.89	....	83	....	3.4	2.4	29.5	29,600	....	650	600	600	98.0
" 30	0.5	1.56	2.8	77	13				25,800	375	325	350	350	98.6
" 31	1.0	1.56	2.6	59	10				17,600	150	220	120	160	99.1
Jan.'(99) 1	2.0	1.53	2.6	49	10	.205	.082	60.0	10,300	230	190	170	200	98.1
" 2	2.0	1.55	2.8	49	10	3.6	1.7	52.8	8,400	200	110	140	150	98.2
" 3	2.0	1 53	2.8	75	10				13,200	210	220	190	210	98.4
" 4	2 0	1.54	2.9	75	10				19,000	170	140	110	140	99.3
" 5	2.0	1.52	3.1	243	10	.262	.082	68.7	17,900	130	120	110	120	99.3
" 6	2.0	1.54	3.4	243	7	4.5	1.7	62.2	26,900	150	100	140	160	99.4
" 7	1.0	1.52	3.5	130	5				21,100	230	190	220	210	99.0
" 8	1.5	1.56	3 5	117	7				26,300	275	230	190	230	99.1
" 9	2.0	1.53	3.6	54	7	.243	.088	63.8	21,600	210	300	230	250	98.8
" 10	1.0	1.52	3.6	106	10	4 3	1.9	55.8	13,300	210	220	160	230	98.3
" 11	1.0	1.58	3 6	123	7				18,900	275	190	170	210	98.9
" 12	1.0	1.48	3.4	129	13				16,200	240	350	475	350	97.8
" 13	1.5	1.38	‡	139	10	.236	.106	55.0	13,700	230		....	230	98.3
" 14	2.0	0.58	1.6	105	....	4.7	2.3	51.0	13,600	....	700	425	550	96.0
" 15	4.0	3.34	2.0	96	25				13,500	475	700	850	650	95.5

* Closed inlet December 9, 4:35 P. M.; closed outlet December 9, 4:35 P. M. Filter not scraped until December 13 on account of freezing weather. Opened inlet, after scraping, December 13, 3:40 P. M.; opened outlet December 13, 4:50 P. M.

† Pipes frozen; these days are not included in average.

‡ Closed inlet January 12, 10 A. M.; closed outlet January 13, 2:45 P. M. Opened inlet, after scraping, January 14, 5 A. M.; opened outlet January 14, 10:35 A. M.

Daily Record of the Operation and Efficiency of Filter No. 13.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
Jan('99)16	4.5	2.78	2.7	91	25				16,200	1,300	1,300	2,900	1,800	88 9
" 17	4.5	2.60	3.5	155	25	.269	.140	48.0	18,300	2,400	2,400	1,800	2,200	88 0
" 18	3.5	2.56	4 0	164	25	5.0	2.8	44.0	21,200	1,500	1,400	1,100	1,300	93 9
" 19	3.0	2.56	5.0	153	25				18,400	1,500	1,500	800	1,300	92.9
" 20	2.0	....	*	....	....				17,200	....	....	....	....	....
" 21	3.0	....	....	....	....				19,200	....	....	....	....	....
" 22	3.5	0.71	1.2	130	....	.271	.096	64.5	14,300	....	....	650	650	95 4
" 23	3.5	2.67	1 7	112	....	5.3	2.3	56.6	14,900	700	900	500	700	95.3
" 24	4.0	2.98	2.0	71	14				11,300	700	550	425	550	95.1
" 25	3.0	2.32	2.0	68	14				6,700	450	140	....	425	93 6

Daily Record of the Operation and Efficiency of Filter No. 14.

March 28	11.0	2.13	0.3	169	....				.....	....	5,000	....	5,000	....
" 29	11.0	2.38	0.3	140	25	.238	.094	60.5	16,600	4,400	....	5,900	5,200	69 9
" 30	10.5	2.44	0.3	115	20	5.0	2.3	54.0	11,200	1,500	2,600	2,400	2,200	80 3
" 31	9.0	2.44	0.3	171	25	.226	.158	30.1	5,700	2,100	2,900	3,000	2,700	52 6
April 1	9.0	2.55	0.3	86	30	4.7	2.9	38.3	9,500	4,200	2,300	1,400	2,600	72 6
" 2	9.5	2.56	0.4	83	30				4,700	2,200	1,500	....	1,800	61.7
" 3	9.5	2.56	0.4	75	25	.....	....	....	6,100	....	....	1,800	1,800	70 5
" 4	9.0	2.56	0.5	80	25	.166	.136	18.0	4,100	1,200	1,500	1,200	1,300	68 3
" 5	7.0	2.54	0.5	75	25	3.5	2.3	34.3	3,600	1,700	1,500	1,300	1,500	58 3
" 6	6.5	2.57	0.6	40	20				3,500	1,300	1,300	900	1,200	65 7
" 7	6.0	2.61	0.7	52	15	.165	.068	58.8	3,400	800	700	800	700	79 4
" 8	7.0	2.58	0.8	90	10	3.4	1.9	44.1	2,700	475	750	650	600	77 8
" 9	8.0	2.61	0.9	50	8				2,100	700	375	....	550	73 8
" 10	8.0	2.60	1.1	92	10	.....	....	....	2,800	....	....	475	475	83 0
" 11	8.5	2.57	1.3	61	14	.126	.074	41.3	3,800	400	325	110	275	92 8
" 12	8.5	2.56	1.6	71	16	2.8	1.3	53.6	1,900	375	210	120	240	87 4
" 13	9.0	2.63	1.9	65	14				2,200	180	120	190	160	92 7
" 14	8.5	2.66	2.1	86	8	.102	.060	41.2	2,400	130	130	220	160	93 3
" 15	9.0	2.67	2.2	39	4	2.3	1.3	43.4	2,300	250	220	350	270	88 3
" 16	10.0	2.66	2.2	43	3				3,500	325	230	....	275	92 1
" 17	13.0	2.66	2.2	34	3	.....	....	....	2,700	....	....	250	250	90 7
" 18	13.0	2.65	2.2	28	3				4,400	375	250	300	300	93 2
" 19	13.0	2.67	2.4	26	3	.086	.058	32.4	3,700	375	300	250	300	91.9
" 20	11.5	2.62	2.6	30	3	1.5	1.0	33.3	5,800	275	190	200	220	96 2
" 21	11.5	2.68	2.7	30	3	.080	.056	30.0	5,900	250	310	200	250	95.8
" 22	12.0	2.68	2.8	33	3	1.6	1.0	37.5	5,700	140	180	180	170	97.0
" 23	13.0	2.67	2.9	28	4				6,300	230	180	....	200	96 8
" 24	12.5	2.65	3.0	25	3	.....	....	..	6,100	....	....	120	120	98 0
" 25	12.0	2.69	3.5	31	3				7,700	180	150	120	150	98 0
" 26	13.0	2.64	4.0	27	4	.102	.060	41.2	5,300	190	120	130	150	97 2
" 27	11.5	2.71	4.3	25	3	2.1	1.2	42.9	12,200	100	250	275	210	98 3
" 28	12.0	2.68	4.8	17	4				9,600	140	150	130	140	98 5
" 29	12.0	2.61	5.2	28	2	.124	.062	50.0	6,000	190	160	170	170	97.2
" 30	13.0	2.56	5.8	9	3	2.3	1.2	47.8	4,100	160	90	....	120	97 1
May 1	14.0	2.59	6.3	37	3	.....	....	....	8,900	....	....	180	180	97 9
" 2	15.5	2.43	8.2	37	3				4,500	160	130	150	150	96 7
" 3	16.0	2 60	9.7	80	4	.136	.068	50.0	6,200	150	150	170	160	97 4
" 4	15.5	2.61	†	38	5	3.2	1.7	46.9	3,300	160	325	220	240	92 7

* Closed inlet January 19, 8:30 A. M.; closed outlet January 21, 9:30 A. M. Opened inlet, after scraping, January 22, 11:10 A. M.; opened outlet January 22, 6:35 A. M.

† Closed inlet May 4, 8:45 A. M.; closed outlet May 4, 12 P. M. Opened inlet, after scraping, May 5, 4:10 P. M.; opened outlet May 5, 7:55 P. M.

Daily Record of the Operation and Efficiency of Filter No. 14.

Date. 1898.	Temperature, Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
May 5	15.0	0.96	0.3	21	6				2,100	....	....	104	170	91.9
" 6	14.0	2.68	0.3	19	5	.118	.064	45.7	2,900	85	75	95	85	97.1
" 7	11.0	2.60	0.3	23	5	2.8	1.6	42.8	1,900	85	110	....	95	95.0
" 8	11.0	2.63	0.3	30	6	.....	....	....	2,700	....	....	95	95	96.5
" 9	12.0	2.57	0.3	24	7	.196	.082	58.2	2,300	95	130	220	150	93.5
" 10	13.0	2.59	0.3	129	20	3.7	1.7	54.1	15,300	350	300	170	275	98.2
" 11	14.0	2.59	0.3	82	18				12,200	240	230	200	220	98.2
" 12	14.0	2.65	0.4	68	18				8,000	190	110	130	140	98.2
" 13	14.0	2.74	0.4	52	18	.152	.080	47.4	4,300	95	140	90	110	97.4
" 14	15.0	2.70	0.4	41	9	3.5	1.8	48.6	3,100	120	90	....	100	96.8
" 15	16.0	2.64	0.4	53	8	.....	....	....	4,000	....	....	190	190	95.2
" 16	17.0	2.62	0.4	68	6				4,500	90	95	65	85	98.1
" 17	17.5	2.61	0.4	36	5	.162	.070	56.8	3,000	70	60	70	65	97.8
" 18	17.0	2.61	0.4	62	4	3.2	1.7	46.8	2,000	43	55	110	70	96.5
" 19	19.0	2.59	0.5	53	3				2,600	95	49	85	75	97.1
" 20	20.0	2.64	0.6	50	2	.116	.072	38.0	1,900	110	44	110	90	95.3
" 21	20.0	2.70	0.6	51	2	2.5	1.3	48.0	2,000	65	65	....	65	96.8
" 22	20.0	2.74	0.7	43	3	.....	....	....	1,500	....	....	49	49	96.7
" 23	20.0	3.59	0.7	111	4				2,500	75	37	55	55	97.8
" 24	20.0	2.59	0.8	136	9	.208	.092	55.8	2,100	80	80	60	75	96.4
" 25	20.0	2.60	0.9	95	13	3.7	1.8	51.4	2,400	110	95	110	100	95.8
" 26	20.0	2.63	1.0	73	13				2,200	110	75	140	110	95.0
" 27	20.0	2.61	1.1	64	8	.138	.066	52.2	2,400	100	48	110	85	96.5
" 28	22.0	2.59	1.2	50	7	3.0	1.6	46.7	1,900	100	120	....	110	94.2
" 29	22.0	2.59	1.2	82	6	.....	....	....	2,900	....	..	85	85	97.1
" 30	22.0	2.61	1.3	62	7	.....	....	....	3,600	....	....	70	70	98.1
" 31	22.0	2.64	1.3	51	8	.152	.074	51.3	1,500	95	70	....	80	94.7
June 1	21.0	2.68	1.3	57	8	2.8	1.7	39.3	1,200	....	65	70	65	94.6
" 2	22.0	2.70	1.3	40	8				1,100	46	65	65	60	94.5
" 3	22.0	2.64	1.4	51	5	.132	.068	48.5	1,300	46	50	37	45	96.5
" 4	22.0	2.70	1.5	41	3	2.7	1.6	40.7	800	45	41	....	43	94.8
" 5	23.0	2.73	1.5	30	3	.....	....	....	900	....	....	46	46	94.9
" 6	23.0	2.56	1.6	38	2	.130	.066	49.2	800	41	55	60	50	93.8
" 7	23.0	2.58	1.6	45	5	2.7	1.3	51.9	700	50	49	40	46	93.4
" 8	24.0	2.67	1.7	38	4	.....	....	....	600	32	29	29	30	95.0
" 9	24.0	2.69	1.7	27	3	.112	.070	37.5	800	40	29	16	28	96.5
" 10	25.0	2.67	1.8	16	2	2.3	1.3	43.5	700	22	22	23	22	96.9
" 11	25.0	2.62	1.8	16	1	.....	....	....	800	19	28	....	24	97.0
" 12	25.0	2.58	2.5	15	2	.116	.056	51.7	700	....	....	31	31	95.6
" 13	26.0	2.58	3.2	14	1	2.3	1.1	52.2	600	lost	34	38	36	94.0
" 14	26.0	2.56	3.7	17	1	.....	....	....	1,000	45	65	34	48	95.2
" 15	26.0	2.55	*	15	1	.116	.066	43.1	800	32	33	35	33	95.9
" 16	24.0	1.68	0.2	12	2	1.7	1.0	41.2	400	20	....	27	32	92.0
" 17	24.0	2.62	0.2	10	1	.....	....	....	200	27	75	29	44	78.0
" 18	25.0	2.61	0.2	12	1	.104	.058	44.2	250	36	28	....	32	87.2
" 19	25.0	2.71	0.2	13	1	1.8	1.0	44.5	200	....	....	23	23	88.5
" 20	25.0	2.65	0.2	12	1	.....	....	....	100	29	25	34	29	71.0
" 21	25.0	2.62	0.2	10	1	.090	.056	37.8	150	21	37	23	27	82.0
" 22	23.0	2.63	0.2	8	0	1.5	0.9	40.0	95	28	28	19	25	73.7
" 23	23.0	2.64	0.2	8	0	.....	....	....	110	32	28	23	28	74.5
" 24	24.0	2.62	0.2	7	0	.090	.058	35.6	190	28	30	37	32	83.2
" 25	24.0	2.62	0.2	6	2	1.7	1.2	29.4	250	16	18	....	17	93.2
" 26	24.0	2.61	0.3	45	2	.....	....	....	4,100	....	....	27	27	99.4
" 27	25.0	2.59	0.3	56	2	.148	.072	51.3	2,400	32	35	18	28	98.8
" 28	25.0	2.59	0.3	67	1	2.5	1.5	40.0	1,000	44	24	24	31	96.9
" 29	25.0	2.59	0.3	45	2	.....	....	....	1,500	20	20	20	20	98.7
" 30	25.0	2.62	0.4	57	2	.112	.060	46.4	1,700	27	12	25	21	98.8
July 1	26.0	2.64	0.3	69	2	2.3	1.2	47.9	1,200	30	23	36	30	97.5

* Closed inlet June 15, 8 A. M.; closed outlet June 16, 8:15 A. M. Opened inlet, after scraping, June 16, 1:30 P. M.; opened outlet, June 16, 5:50 P. M.

Daily Record of the Operation and Efficiency of Filter No. 14.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
July	2	26.0	2.56	0.4	134	3	.182	.070	61.5	2,100	41	34	....	38	98.2
"	3	26.0	2.73	0.4	111	3	3.3	1.5	54.5	1,500	....	....	60	60	96.0
"	4	26.0	2.60	0.4	88	3				1,200	41	....	34	38	96.8
"	5	26.0	2.62	0.4	68	3	.128	.072	43.8	1,500	55	55	24	45	97.0
"	6	26.0	2.61	0.5	53	3	2.7	1.6	40.8	2,500	46	24	23	31	98.8
"	7	27.0	2.61	0.5	37	4				3,200	20	46	55	40	98.7
"	8	27.0	2.65	0.5	23	3	.134	.078	41.8	550	47	39	19	35	93.6
"	9	27.0	2.69	0.5	59	4	2.6	1.5	42.3	650	34	65	....	50	92.3
"	10	25.0	2.59	0.6	94	3				325	....	....	44	44	86.5
"	11	25.0	2.60	0.8	33	3	.126	.064	49.2	1,400	24	55	29	36	97.4
"	12	24.0	2.70	1.0	36	3	2.3	1.4	39.2	1,200	35	26	27	29	97.6
"	13	24.0	2.68	1.2	38	5				1,500	34	16	16	22	98.5
"	14	24.0	2.65	1.5	28	3	.108	.068	37.0	650	19	29	34	27	95.8
"	15	25.0	2.64	1 8	22	3	2.1	1.3	38.1	600	27	23	24	25	95.8
"	16	26.0	2.65	* 2.1	16	3				550	95	36	....	65	88.2
"	17	26.0	2 54	2.4	13	3	.114	.060	47.4	950	....	....	25	25	97.4
"	18	26.0	2.63	3.3	16	3	2.1	1.3	38.1	450	60	41	40	47	89.6
"	19	26.0	2.66	3.6	18	2				550	25	55	25	35	93.6
"	20	27.0	2.66	*	8	1	.110	.058	47.2	3,200	26	23	29	26	99.2
"	21	27.0	2.31	....	16	2	2.2	1.2	45.5	1,100	48	41	....	44	96.0
"	22	27.0	0.46	....	23	2				850	....	....	85	85	90.0
"	23	27.0	2.65	0.2	78	2				4,800	57	26	....	42	99.1
"	24	27.0	2.59	0.2	133	4	.188	.060	68.1	8,400	....	....	50	50	99.4
"	25	28.0	2.58	0.2	187	4	3.1	1.3	58.1	5,500	20	160	28	75	98.6
"	26	27.0	2.65	0.2	113	3				3,300	32	21	33	29	99.1
"	27	28.0	2.64	0.3	90	4	.168	.074	56.0	3,600	17	19	25	20	99.4
"	28	28.0	2.64	0.3	66	3	3.0	1.3	56.7	2,500	50	20	37	36	98.6
"	29	27.0	2.63	0.3	70	8				8,000	43	38	60	47	99.4
"	30	27.0	2.62	0.3	131	9	.176	.072	59.1	3,300	34	45	....	40	98.8
"	31	27.0	2.61	0.4	192	10	3.1	1.4	54.8	2,200	....	....	55	55	97.5
Aug.	1	26.0	2.61	0.4	315	9				5,400	43	38	60	42	99.2
"	2	26.0	2.64	0.4	185	14	.224	.074	67.0	1,100	40	33	40	38	96.5
"	3	26.0	2.55	0.4	76	9	3.5	1.2	65.7	3,200	47	27	60	45	98.6
"	4	26.0	2.65	0.4	189	13				2,300	32	32	49	38	98.3
"	5	26.0	2.62	0.4	140	16	.176	.076	56.8	1,600	55	44	55	50	96.8
"	6	25.0	2.61	0.5	91	13	3.3	1.6	51.5	1,700	70	65	....	70	95.9
"	7	25.0	2.67	0.5	87	11	.....	....	....	2,500	....	....	43	43	98.3
"	8	26.0	2.66	0.5	100	11				4,100	65	40	49	50	98.8
"	9	25.0	2.65	0.5	113	15				4,200	60	55	850	325	92.3
"	10	25.0	2.59	0.6	176	16	.190	.072	62.1	4,400	60	40	50	50	98.9
"	11	25.0	2.56	†	207	13	8.2	1.5	53.1	3,800	45	42	49	45	98.8
"	12	25.0	0.17		266	....				3,600	....	....	....	....	....
"	13	25.0	0.97	0.2	280	....				4,500	....	32	....	50	98.9
"	14	25.0	1.48	0 2	212	20	.234	.104	55.6	6,100	....	....	325	325	94.7
"	15	24.0	1.57	0.3	237	25	5.0	2.0	60.0	3,200	130	120	140	130	95.9
"	16	25.0	2.25	0.4	241	25				2,300	85	90	170	110	95.2
"	17	25.0	2.68	0.4	199	30				3,100	160	110	127	130	95.8
"	18	25.0	2.63	0.5	130	30	.180	.110	38.9	1,600	150	140	210	170	89.4
"	19	24.0	2.58	0.5	100	25	4.4	2.7	38.7	1,700	95	110	140	110	93.5
"	20	24.0	2 58	0.7	143	25				5,100	150	75	....	110	97.8
"	21	25.0	2.57	0.8	136	16				4,800	....		170	170	96.5
"	22	25.0	2.61	0 8	137	15	.186	.104	44.1	3,800	95	75	80	85	97.8
"	23	26.0	2.56	1.0	139	15	4.1	2.2	46.4	4,800	110	110	120	110	97.7
"	24	25.0	2.62	0.9	113	20				3,400	100	100	120	110	96.8

* Closed inlet July 20, 10:30 P. M.; closed outlet July 21, 7 P. M. Opened inlet, after scraping, July 22, 12 M.; opened outlet, July 22, 4:45 P. M.

† Closed inlet August 11, 9:50 A. M.; closed outlet August 12, 1:45 A. M. Opened inlet, after scraping, August 12, 1:55 P. M.; opened outlet August 13, 9 A. M.

Daily Record of the Operation and Efficiency of Filter No. 14.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
Aug. 25	26.0	2.66	0.8	80	18				1,400	100	140	150	130	90.7
" 26	25.0	2.53	0.9	75	18	.155	.090	42.0	1,000	150	140	....	145	85.5
" 27	25.5	....	*	....	....	3.7	2.0	46.0	1,000	....	....	....	....	....
" 28	24.0	....	....	....	....				1,600	....	....	....	....	....
" 29	24.5	....	....	....	....				1,400	....	....	....	....	....
" 30	25.5	0.31	0.2	115	6	.166	.086	48.3	1,500	....	....	100	100	93.3
" 31	25.5	1.84	0.3	93	5	3.5	1.8	48.6	1,500	80	110	75	90	94 0
Sept. 1	26.0	2.51	0.2	66	12				2,300	85	55	55	65	97.2
" 2	26 0	2.63	0.4	57	12				2,200	65	55	65	60	97.3
" 3	27 0	2.57	0 3	53	10	.165	.088	46.7	1,700	55	50	....	50	97.1
" 4	28.0	2.60	0.4	38	9	3.9	2.0	48.8	3,300	....	....	85	85	97.4
" 5	25.0	2.59	0.5	33	9				1,500	70	....	85	80	94.7
" 6	27.0	2.61	0.5	20	8				1,000	65	65	65	65	93.5
" 7	25.0	2.65	0.6	12	9	.138	.102	26.2	450	49	70	44	55	87.8
" 8	23.0	2.63	0.7	10	8	3 3	2.1	36.4	600	43	40	65	49	91.8
" 9	23.0	2.59	0.7	9	7				850	35	49	24	36	95.8
" 10	22.0	2.60	0.9	14	8				1,500	35	55	....	45	97.0
" 11	22.0	2.63	1.2	12	5	.130	.082	37.0	1,600	....	..	39	39	97.6
" 12	21.0	2.62	1.3	7	5	2.8	1.9	32.1	550	22	27	28	26	95.3
" 13	21.0	2.60	1.5	14	4				220	23	19	27	23	89.5
" 14	21.0	1.66	1.5	10	4	.....	....	....	275	32	38	....	35	87.3

Permanently stopped September 14, 4 P. M.

Daily Record of the Operation and Efficiency of Filter No. 15.

March 28	11.0	2.76	0.3	169	....	.238	.130	45.4	....	....	1,600	....	1,600	....
" 29	11.0	2.41	0.3	140	40	5.0	3.0	40.0	16,600	2,800	....	4,800	3,800	77.1
" 30	10.5	2.44	0.3	115	35				11,200	3,900	3,900	3,200	3,700	66 9
" 31	9.0	2.49	0.3	171	35				5,700	900	2,200	2,600	1,900	66.7
April 1	9.0	2.49	0.3	86	40	.226	.154	31.9	9,500	2,100	1,300	1,200	1,500	84.2
" 2	9.5	2.60	0.4	83	35	4.7	3.2	32.0	4,700	1,600	1,600	....	1,600	66.0
" 3	9.5	2.59	0.4	75	25	.....	....	....	6,100	....	....	1,000	1,000	83.6
" 4	9.0	2.61	0.4	80	15				4,100	1,000	2,900	2,800	2,200	46.4
" 5	7.0	2.59	0.5	75	15	.166	.128	22.9	3,600	1,400	1,300	2,200	1,600	55.6
" 6	6.5	2.58	0.6	40	20	3.5	2.3	34.3	3,500	1,400	1,600	1,100	1,400	60.0
" 7	6.0	2.57	0.6	52	15				3,400	1,000	750	400	700	79.4
" 8	7.0	2.54	0.7	90	15	.165	.072	56.4	2,700	500	800	1,000	750	72.2
" 9	8.0	2.52	0.8	50	15	3.4	1.9	44.1	2,100	750	500	....	600	71.4
" 10	8.0	2.47	1.1	92	20	.....	....	....	2,800	....	....	375	375	86.6
" 11	8.5	2.65	1.2	61	20				3,800	230	110	140	160	95.8
" 12	8.5	2.63	1.4	71	15	.126	.084	33.4	1,900	240	190	75	170	91.1
" 13	9.0	2.60	1.6	65	15	2.8	1.4	50.0	2,200	160	170	160	160	92.7
" 14	8.5	2.58	1.7	86	14				2,400	150	130	110	130	94.6
" 15	9.0	2.63	1.8	39	12	.102	.068	33.4	2,300	110	180	180	160	93.0
" 16	10.0	2.61	1.8	43	10	2.3	1.2	47.8	3,500	300	140	....	220	93.7
" 17	13.0	2.60	1.8	31	2	.....	....	....	2,700	....	....	250	250	90.7
" 18	13.0	2.59	2.1	23	3				4,400	325	230	300	275	93.8
" 19	13.0	2.71	2.1	26	4	.086	.062	27.8	3,700	250	140	75	160	95.7
" 20	11.5	2.64	2.3	30	4	1.5	1.1	26.7	5,800	180	180	200	190	96.7
" 21	11.5	2.61	2.3	30	3				5,900	250	160	90	170	97.1
" 22	12.0	2.66	2.5	33	3	.080	.054	32.5	5,700	95	85	190	120	97.9
" 23	13.0	2.70	2.7	28	3	1.6	1.0	37.5	6,300	150	240	....	200	96.8
" 24	12.5	2.67	2.8	25	4	.....	....	....	6,100	....	....	120	120	98.0

* Closed inlet August 26, 7:50 A. M ; closed outlet August 26, 11:20 P. M. Opened inlet, after scraping, August 29, 2:10 P. M.; opened outlet August 30, 6 P. M.

Daily Record of the Operation and Efficiency of Filter No. 15.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
April 25	12.0	2.62	3.3	31	3	.102	.066	35.3	7,700	95	120	190	140	98.2
" 26	13.0	2.58	4.1	27	4	2.1	1.2	42.9	5,300	110	100	170	130	97.5
" 27	11.5	2.54	4.6	25	2				12,300	140	250	210	200	98.4
" 28	12.0	2.66	5.4	17	3	.124	.064	48.4	9,600	160	140	90	130	98.6
" 29	12.0	2.64	5.9	28	4	2.3	1.4	39.1	6,000	110	85	110	100	98.3
" 30	13.0	2.69	6.9	9	4				4,100	120	90	....	100	97.6
May 1	14.0	2.71	7.7	37	4	.....	....	....	8,900	....	....	100	100	98.9
" 2	15.5	2.66	10.2	37	3				4,500	110	85	95	95	97.9
" 3	16.0	2.06	*	80	6	.136	.070	48.5	6,200	140	160	130	140	97.7
" 4	15.5	0.79	0.3	38	7	3.2	1.7	46.9	3,300	lost	....	180	180	94.2
" 5	15.0	2.65	0.3	21	6				2,100	170	110	75	120	94.3
" 6	14.0	2.62	0.3	19	9	.118	.068	42.5	2,900	85	95	46	75	97.4
" 7	11.0	2.56	0.3	23	8	2.8	1.7	39.3	4,900	120	65	....	90	95.2
" 8	11.0	2.71	0.3	30	8				2,700	....	....	75	75	97.2
" 9	12.0	2.62	0.4	24	7	.....	....	....	2,300	100	130	180	140	93.9
" 10	13.0	2.63	0.4	129	9	.196	.081	57.2	15,300	200	120	140	150	99.0
" 11	14.0	2.65	0.4	82	20	3.7	2.0	45.9	12,200	180	150	140	160	98.7
" 12	14.0	2.61	0.4	68	16				8,000	140	95	120	120	98.5
" 13	14.0	2.61	0.5	52	11	.152	.086	43.4	4,300	120	80	75	90	97.9
" 14	15.0	2.06	0.5	41	9	3.5	2.1	40.0	3,100	60	90	....	75	97.6
" 15	16.0	2.70	0.5	53	9	.....	....	....	4,000	....	....	90	90	97.8
" 16	17.0	2.49	0.5	68	8				4,500	140	95	140	120	97.3
" 17	17.5	2.68	0.5	36	6	.162	.076	53.1	3,000	120	110	130	120	96.0
" 18	17.0	2.73	0.5	62	5	3.2	1.6	50.0	2,000	350	200	lost	275	86.2
" 19	19.0	2.71	0.5	53	4				2,600	240	170	210	210	91.9
" 20	20.0	2.70	0.6	50	5	.116	.074	36.3	1,900	70	70	40	60	96.8
" 21	20.0	2.70	0.6	51	4	2.5	1.5	40.0	2,000	45	60	....	50	97.5
" 22	20.0	2.72	0.7	43	6	.....	....	....	1,500	....	....	44	44	97.1
" 23	20.0	2.62	0.8	111	9				2,500	60	55	90	70	97.2
" 24	20.0	2.68	0.9	136	20	.208	.098	52.9	2,100	80	75	100	85	96.0
" 25	20.0	2.66	1.0	95	20	3.7	1.9	48.7	2,400	85	75	95	85	96.5
" 26	20.0	2.63	1.2	73	16				2,200	70	60	70	65	97.0
" 27	20.0	2.63	1.3	64	9	.138	.070	49.3	2,400	75	55	75	70	97.1
" 28	22.0	2.61	1.4	50	9	3.0	1.6	46.7	1,900	75	90	....	80	95.8
" 29	22.0	2.58	1.5	82	10	.....	....	....	2,900	....	....	60	60	97.9
" 30	22.0	2.64	1.6	62	11	.....	....	....	3,000	....	....	80	80	97.8
" 31	22.0	2.66	1.7	51	13	.152	.072	52.6	1,500	50	90	....	70	95.3
						2.8	1.8	35.7						

* Closed inlet May 3, 8:20 A. M.; closed outlet May 4, 11 A. M. Opened inlet, after scraping. May 4, 7:55 P. M.; opened outlet May 4, 11:05 P. M.

Daily Record of the Operation and Efficiency of Filter No. 18.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Effluent. 4 P M	Effluent. 12 P M	Effluent. Average.	Average Bacterial Efficiency.
Sept.	1	26.0	0.77	0.1	66	7				2,300	.....	.....	47,000	47,000	—1944.0
..	2	26.0	2.41	0.1	57	10				2,200	28,000	20,000	19,000	22,300	— 909.0
..	3	27.0	2.01	0.1	53	13	.165	.104	37.1	1,700	1,600	15,000	.....	8,300	— 388.0
..	4	28.0	1.73	0.1	38	8	3.9	2.3	41.1	3,300	.....	.....	8,000	8,000	— 142.5
..	5	25.0	1.63	0.2	33	6				1,500	2,800	2,100	2,400	2,400	— 60.0
..	6	27.0	2.58	0.2	20	5				1,000	1,700	1,800	1,200	1,600	— 60.0
..	7	25.0	2.59	0.2	12	3	.138	.092	33.4	450	1,000	600	600	750	— 66.6
..	8	23.0	2.58	0.2	10	4	3.3	2.1	36.4	600	700	475	350	500	16.7
..	9	23.0	2.58	0.3	9	3				850	300	275	240	275	67.6
..	10	22.0	2.60	0.4	14	3				1,500	240	275	.....	260	82.7
..	11	22.0	2.58	0.6	12	1				1,600	.....	.....	120	120	92.5
..	12	21.0	2.62	0.8	7	0	.130	.062	37.0	550	150	120	120	130	76.4
..	13	21.0	2.57	0.9	4	2	2.8	1.7	39.2	220	160	140	170	160	27.3
..	14	21.0	1.67	0.9	10	0				275	150	120	.....	140	49.1

Permanently stopped September 14, 4 P. M.

Daily Record of the Operation and Efficiency of Filter No. 19.

Sept.	1	26.0	0.77	0.1	66	10				2,300	.....	.....	1,700	1,700	26.1
..	2	26.0	2.60	0.1	57	11				2,200	3,700	6,000	3,700	4,500	—100.0
..	3	27.0	2.63	0.1	53	14	.165	.108	34.6	1,700	500	13,000	.....	6,800	—300.0
..	4	28.0	2.58	0.1	38	8	3.9	2.3	41.1	3,300	.....	.....	2,600	2,600	21.2
..	5	25.0	2.56	0.1	33	6				1,500	2,900	.....	1,900	2,400	— 60.0
..	6	27.0	2.63	0.1	20	5				1,000	1,800	1,700	1,400	1,600	— 60.0
..	7	25.0	2.63	0.2	12	3	.138	.088	36.3	450	1,200	1,000	850	1,000	—122.0
..	8	23.0	2.64	0.2	10	3	3.3	2.1	36.4	600	800	650	550	650	— 8.3
..	9	23.0	2.63	0.3	9	2				850	450	475	550	500	41.2
..	10	22.0	2.58	0.4	14	3				1,500	350	475	.....	410	72.6
..	11	22.0	2.59	0.8	12	1	.130	.084	35.4	1,600	.....	.....	250	250	84.4
..	12	21.0	2.62	1.1	7	1	2.8	1.7	39.2	550	425	300	275	325	40.9
..	13	21.0	2.60	1.2	4	2				220	300	550	240	350	— 59.1
..	14	21.0	1.71	1.3	10	1	.... ..	....	....	275	275	325	.....	300	— 9.1

Permanently stopped September 14, 4 P. M.

APPENDIX II.

MODIFIED ENGLISH FILTERS.

Daily Record of the Operation and Efficiency of Filter No. 16.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Applied Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Bacteria per Cubic Centimeter. Effluent. 4 P M	Bacteria per Cubic Centimeter. Effluent. 12 P M	Bacteria per Cubic Centimeter. Effluent. Average.	Average Bacterial Efficiency.
Aug. 8	26.0	1.33	0.3	73	6				4,100	....	500	450	475	88.4
" 9	25.0	4.00	0.3	70	5				4,200	325	425	350	375	91.1
" 10	25.0	4.02	0.4	65	3	.190	.070	63.2	4,400	150	100	170	140	96.8
" 11	25.0	4.05	0.5	52	1	3.2	1.4	56.3	3,800	150	....	....	150	96.1
" 12	25.0	4.02	0.5	67	2				3,600	....	....	....	....	....
" 13	25.0	4.00	0.6	67	3				4,800	650	450	....	550	88.5
" 14	25.0	3.96	0.7	55	2	.234	.076	67.5	6,100	....	....	100	100	98.4
" 15	24.0	3.46	0.8	24	1	5.0	1.5	70.0	3,200	49	250	70	120	96.2
" 16	25.0	3.94	0.9	60	1				2,300	37	44	60	47	97.9
" 17	25.0	2.88	1.2	76	11				3,100	95	....	60	75	97.6
" 18	25.0	3.94	1.5	31	7	.180	.080	55.5	1,600	75	60	55	60	96.2
" 19	24.0	4.01	1.8	41	2	4.4	1.7	61.4	1,700	37	48	75	55	96.8
" 20	24.0	3.99	1.9	42	5				5,100	34	32	....	33	99.4
" 21	25.0	4.04	2.0	55	1				4,800	....	....	23	23	99.5
" 22	25.0	4.06	2.2	31	1	.186	.072	61.3	3,800	39	35	47	40	99.9
" 23	26.0	3.99	2.7	64	2	4.1	1.3	68.3	4,800	26	32	32	30	99.4
" 24	25.0	3.99	3.1	40	0				3,400	50	26	24	33	99.0
" 25	26.0	3.96	3.3	34	0				1,400	19	30	28	26	98.1
" 26	25.0	3.96	4.2	60	2	.155	.072	53.5	1,000	26	37	31	31	96.9
" 27	25.5	1.51	*	24	4	3.7	1.5	59.5	1,000	32	....	....	32	96.8
" 28	24.0	3.77	0.5	30	2				1,600	....	....	21	33	97.9
" 29	24.5	3.91	0.8	52	1				1,400	33	21	20	25	98.2
" 30	25.5	4.15	0.9	34	0	.166	.076	54.3	1,500	35	30	42	36	97.6
" 31	25.5	4.00	1.2	30	0	3.5	1.3	62.9	1,500	41	39	49	43	97.1
Sept. 1	26.0	4.02	1.3	26	1				2,300	25	21	38	28	98.8
" 2	26.0	4.07	0.9	41	1				2,200	24	90	45	55	97.5
" 3	27.0	4.15	0.7	35	7	.165	.092	44.3	1,700	55	34	....	44	97.4
" 4	28.0	4.16	0.7	26	9	3.9	2.2	43.6	3,300	....	....	47	47	97.6
" 5	25.0	4.08	0.7	25	8				1,500	28	....	41	34	97.7
" 6	27.0	4.13	0.7	16	6				1,000	34	19	20	24	97.6
" 7	25.0	4.08	0.7	14	7	.138	.102	26.2	450	24	34	29	29	93.6
" 8	23.0	....	†	11	4	3.3	2.2	33.3	600	23	28	....	26	95.7
" 9	23.0	0.94	0.2	....	....				850	....	....	55	55	93.5
" 10	22.0	4.12	0.2	12	5				1,500	85	230	....	160	86.3
" 11	22.0	4.10	0.3	8	2	.130	.084	35.4	1,600	....	....	110	110	93.1
" 12	21.0	4.05	0.4	8	2	2.8	2.0	28.5	550	60	55	31	49	91.1
" 13	21.0	4.00	0.5	8	2				220	25	34	42	34	84.5
" 14	21.0	3.97	0.5	10	2				275	28	31	75	45	83.6
" 15	22.0	8.95	0.7	12	3	.118	.068	42.4	2,600	36	23	23	27	95.8
" 16	22.0	4.04	0.8	11	3	2.0	1.5	25.0	2,100	43	23	27	31	98.5
" 17	21.0	4.00	0.9	12	0				1,400	33	16	....	24	98.3
" 18	22.0	3.94	1.0	18	1				4,200	....	....	20	20	99.5
" 19	22.0	3.92	1.2	33	1	.114	.072	36.8	2,200	14	24	22	20	99.1
" 20	21.0	3.92	1.4	11	1	2.2	1.4	36.4	1,900	26	29	21	25	98.7
" 21	22.0	4.09	1.6	10	1				1,400	25	25	24	25	98.2

* Closed inlet August 27, 12:10 A. M.; closed outlet August 27, 9:30 A. M. Opened inlet, after scraping, August 27, 6:50 P. M.; opened outlet August 28, 1:05 A. M.

† Closed inlet September 8, 1:30 P. M.; closed outlet September 9, 2:10 P. M. Opened inlet, after scraping, September 9, 5 P. M.; opened outlet September 9, 9:20 P. M.

Daily Record of the Operation and Efficiency of Filter No. 16.

Date. 1898.		Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Applied Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
Sept.	22	23.0	4.07	1.9	16	1				1,200	33	30	16	26	97.8
"	23	22.0	4.05	2.9	27	2	.122	.070	42.6	5,000	20	9	10	13	99.7
"	24	23.0	4.15	3.5	30	1	2.1	1.6	23.8	4,200	10	24	....	17	99.6
"	25	22.0	4.01	3.6	15	1				11,900	....	....	9	9	99.9
"	26	23.0	....	*	....	1				2,000	7	19	....	13	99.3
"	27	23.0	0.89	0.4	17	....	.121	.064	47.5	700	....	....	44	44	93.7
"	28	22.0	4.95	0.4	21	0	2.0	1.4	30.0	2,200	38	10	23	24	98.9
"	29	22.0	4.96	0.4	25	1				1,400	13	33	19	22	98.4
"	30	23.0	4.93	0.4	26	1				2,300	14	17	5	12	99.5
Oct.	1	23.0	4.92	0.4	12	1	.120	.076	36.7	1,300	7	16	....	12	99.1
"	2	23.0	5.05	0.4	9	1	1.9	1.5	21.0	1,000	....	....	7	7	99.3
"	3	23.5	5.05	0.4	7	....				450	11	14	21	15	96.7
"	4	24.0	5.01	0.5	7	1				2,000	14	12	14	13	99.3
"	5	23.5	4.99	0.5	10	1	.093	.066	29.0	1,000	21	23	13	19	98.1
"	6	23.0	5.01	0.5	11	0	1.7	1.2	29.5	15,300	14	16	15	15	99.9
"	7	21.5	4.69	0.6	14	0				5,300	13	12	15	13	99.8
"	8	21.5	5.37	0.7	15	1				4,400	8	8	....	8	99.8
"	9	21.0	5.02	0.7	10	1	.086	.054	37.2	4,000	....	....	13	13	99.9
"	10	20.0	4.98	0.7	8	0	1.4	1.0	28.6	4,200	13	19	17	16	99.6
"	11	21.0	4.95	0.9	6	0				2,400	12	7	9	9	99.6
"	12	20.0	4.96	0.9	6	0				1,600	13	8	11	11	99.3
"	13	18.0	5.01	1.1	12	0	.094	.064	31.9	1,100	15	16	12	14	98.8
"	14	17.0	5.00	1.3	17	0	1.6	1.1	31.3	1,700	11	14	13	13	99.2
"	15	16.0	4.93	1.5	16	0				1,800	13	12	....	12	99.3
"	16	10.0	4.87	1.6	20	0				1,000	....	24	22	23	97.7
"	17	15.5	4.83	1.9	22	1	.108	.076	29.6	1,800	8	13	19	13	99.3
	18	14.0	4.92	2.6	10	5	1.9	1.1	42.2	3,100	33	23	18	25	99.2
	19	13.0	5.19	3.0	8	2				2,100	24	12	16	17	99.2
"	20	13.0	5.04	3.5	10	1				9,600	40	60	38	46	99.5
"	21	14.0	2.61	0.5†	11	....	.141	.062	56.0	5,900	....	....	85	85	98.6
"	22	12.0	5.07	0.5	14	1	2.3	1.1	52.2	2,000	55	23	....	39	98.1
"	23	11.0	5.05	0.5	12	1				1,900	15	27	19	20	99.0
"	24	12.0	5.06	0.5	14	1				1,200	22	22	17	20	98.3
"	25	12.0	5.07	0.5	16	1	.106	.064	39.6	700	20	19	21	20	97.1
"	26	12.0	5.10	0.5	12	1	1.8	1.3	27.8	900	17	14	30	20	97.8
"	27	11.0	5.07	0.7	17	1				3,000	26	14	25	22	99.3
"	28	10.0	4.72	0.9	43	3				2,400	20	24	55	33	98.6
"	29	9.0	4.99	1.8	64	8	.154	.070	54.5	5,400	60	37	....	48	99.1
"	30	9.5	4.83	2.1	32	1	3.7	1.4	62.2	5,400	14	6	12	11	99.8
"	31	9.0	4.72	2.9	29	0				5,300	10	18	12	12	99.8
Nov.	1	8.5	4.61	3.6	33	0				5,500	6	11	7	8	99.9
"	2	9.0	4.62	4.0	75	0	.161	.082	49.0	4,400	9	9	25	14	99.7
"	3	9.0	2.62	0.6‡	73	....	4.0	2.0	50.0	3,500	....	....	150	150	95.7
"	4	9.0	4.56	0.6	59	12				3,200	170	150	140	150	95.3
"	5	10.5	4.65	0.8	49	7				3,800	130	90	....	110	97.1
"	6	10.5	4.65	1.4	33	3	.143	.084	41.3	2,800	38	25	55	39	98.6
"	7	9.0	4.87	1.4	27	3	3.8	2.5	34.2	2,000	55	65	49	55	97.2
"	8	9.0	4.85	1.4	49	8				2,000	60	50	60	55	97.2
"	9	9.5	4.84	1.4	43	7				6,500	95	85	65	80	98.8
"	10	10.0	4.85	1.5	44	9	.154	.082	46.7	5,900	70	65	42	60	99.0
"	11	8.5	4.67	1.8	49	7	3.6	2.3	36.1	11,800	110	70	90	90	99.2
"	12	7.5	4.56	3.2	50	6				19,400	65	65	....	65	99.7

* Closed inlet September 26, 7:35 A. M.; closed outlet September 26, 6:30 P. M. Opened inlet, after scraping, September 27, 2:40 P. M.; opened outlet September 27, 7:45 P. M.

† Closed inlet October 20, 8:10 P. M.; closed outlet October 21, 4:30 A. M. Opened inlet, after scraping, October 21, 11:30 A. M.; opened outlet October 21, 4 P. M.

‡ Closed inlet November 2, 6:20 P. M.; closed outlet November 3, 5 A. M. Opened inlet, after scraping, November 3, 1:30 P. M.; opened outlet November 3, 3:50 P. M.

Daily Record of the Operation and Efficiency of Filter No. 16.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Applied Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	Bacteria per Cubic Centimeter. Effluent. 4 P M	Bacteria per Cubic Centimeter. Effluent. 12 P M	Bacteria per Cubic Centimeter. Effluent. Average.	Average Bacterial Efficiency.
Nov. 13	7.5	3.90	3.7	101	2	.274	.070	74.5	36,500	27	48	....	38	99.9
" 14	8.0	1.44	0.4*	72	....				37,800	....	....	130	130	99.7
" 15	8.0	5.09	1 6	26	0	5.1	1.5	70.6	31,800	60	55	41	50	99.8
" 16	7.0	4.94	2.3	25	0				21,300	34	35	21	30	99.9
" 17	7.0	4.83	3.2	31	0				23,000	31	39	22	31	99 9
" 18	8 0	4.66	4.1	27	0	.212	.066	68.9	25,800	17	21	14	17	99 9
" 19	9.0	2.78	0.5†	29	0	5.4	1.7	68.5	18,900	24	....	....	24	99 9
" 20	8.0	4.69	1 1	26	1				8,700	65	28	50	48	99 4
" 21	8.0	4.60	1.7	24	1				7,300	29	26	6	20	99.7
" 22	8.5	4.74	2.1	41	0	.187	.100	46.6	6,200	25	31	65	40	99 4
" 23	10.5	4.93	2.1	43	7	4.8	1.9	60.4	5,600	110	130	170	140	97.5
" 24	5.0	....	‡	42	....				5,800	....	....	....	....	....
" 25	4.0	4 69	0.5	40	7				5,800	160	275	130	190	96 7
" 26	3.0	4.93	0.5	34	8	.123	.090	26.8	3,600	190	130	275	200	94.4
" 27	2.0	4 91	0.5	30	....	3.3	2.4	27.3	3,400	....	250	120	180	94 7
" 28	2.0	4.96	0.6	29	11				3,100	195	120	180	160	94 8
" 29	2.5	4.89	0.6	20	7				4,000	160	190	130	160	96 0
" 30	3.0	4.62	0.6	21	7	.111	.084	24.4	3,800	90	70	100	85	97 8
Dec. 1	8.0	4.90	0.7	19	5	2.8	2.2	21.5	3,100	80	80	85	80	97.4
" 2	2.5	4.89	0.8	20	9				4,800	110	110	100	110	97 7
" 3	2.5	5.09	0.9	16	5				3,800	85	220	....	150	96.1
" 4	4.0	5.07	0.9	22	6	.101	.076	24.7	4,000	50	75	100	75	98 1
" 5	2.5	5.02	1.1	16	6	2.5	1.7	32.0	3,200	55	43	49	49	98.5
" 6	1.5	5.10	1.3	16	5				3,600	50	40	110	70	98 1
" 7	1.0	5.03	1.4	13	5				2,500	75	26	38	46	98 2
" 8	1.0	4.91	1.6	110	7	.212	.078	63.2	30,400	500	2,400	4,300	2,400	92.1
" 9	2.0	4 73	2.6	87	18	4.1	1.8	56.1	70,700	6,500	3,000	3,100	4,200	94 1
" 10	1.0	2.13	....	68	1				43,900	1,800	....	....	1,800	95 9

Daily Record of the Operation and Efficiency of Filter No. 17.

Aug. 8	26.0	0.84	0.2	73	3				4,100	....	....	225	225	94.5
" 9	25.0	2.60	0.3	70	3	.190	.076	60.0	4,200	425	500	220	375	91.1
" 10	25.0	2.60	0.3	65	3	3.2	1.4	56.3	4,400	170	375	....	275	93.8
" 11	25.0	2.60	0.3	52	1				3,800	....	....	....	....	....
" 12	25.0	2.60	0.3	67	2				3,600	800	500	400	550	84.7
" 13	25.0	2.32	0.3	67	2				4,800	325	375	....	350	92.7
" 14	25.0	2.52	0.4	55	1	.234	.072	69.2	6,100	....	....	130	130	97.9
" 15	24.0	2 27	0.5	24	1	5.0	1.3	74.0	3,200	50	190	130	120	96.2
" 16	25.0	2.55	0.6	60	1				2,300	60	41	43	48	97.9
" 17	25 0	1.85	0.6	76	2				3,100	165	....	75	120	96 1
" 18	25 0	2.58	1.0	31	10	.180	.078	56.7	1,600	80	36	60	60	96 2
" 19	24.0	2 62	1 2	41	6	4.4	1.7	61.4	1,700	47	34	47	43	97.5
" 20	24 0	2.57	1.2	42	3				5,100	35	35	....	35	99.3
" 21	25.0	2.61	1.3	55	1				4,800	....	....	39	39	99.2
" 22	25.0	2.57	1.5	31	1	.186	.072	61.3	3,800	25	40	39	35	99 1
" 23	26.0	2,57	1.8	64	1	4.1	1.3	68.3	4,800	32	25	34	30	99 4
" 24	25.0	2.57	2.2	40	0				3,400	28	24	22	25	99.3

* Closed inlet November 13, 12:20 P. M.; closed outlet November 13, 10:15 P. M. Opened inlet, after scraping, November 14, 12:25 P. M.; opened outlet November 14, 5 P. M.

† Closed inlet November 18, 11:45 P. M.; closed outlet November 19, 10 A. M. Opened inlet, after scraping, November 19, 2:05 P. M.; opened outlet November 19, 6 P. M. Filter accidentally drained November 24.

‡ Closed inlet ——; closed outlet November 24, 8 A. M. Opened inlet, after scraping, November 24, 9:45 P. M.; opened outlet November 25, 1:15 A. M.

Daily Record of the Operation and Efficiency of Filter No. 17.

Date. 1898.	Temperature. Deg. C.	Av. Rate of Filtration. Million Gallons per Acre per Day.	Loss of Head at 12 P. M. Feet.	Suspended Matter. Parts per Million. Applied Water.	Suspended Matter. Parts per Million. Effluent.	Total Organic Matter. Parts per Million. Subsided Water.	Total Organic Matter. Parts per Million. Effluent.	Total Organic Matter. Percentage Removal.	Bacteria per Cubic Centimeter. Subsided Water.	Bacteria per Cubic Centimeter. Effluent. 8 A M	4 P M	12 P M	Average.	Average Bacterial Efficiency.
Aug. 25	26.0	2.60	2.5	34	0				1,400	23	26	26	25	98.2
" 26	25.0	2.32	3.0	60	1	.155	.072	53.5	1,000	33	29	27	30	97.0
" 27	25.5	2.24	2.7	24	1	3.7	1.3	64.9	1,000	29	47	....	38	96.2
" 28	24.0	2.53	3.4	30	2				1,600	....	....	21	21	98.7
" 29	24.5	2.49	3.5	52	1				1,400	22	23	31	25	98.2
" 30	25.5	2.52	*	34	0	.166	.074	55.5	1,500	32	14	32	26	98.3
" 31	25.5	1.26	0.2	30	....	3.5	1.2	65.7	1,500	....	....	49	49	96.7
Sept. 1	26.0	2.33	0.2	26	1				2,300	24	....	....	24	99.0
" 2	26.0	2.43	0.2	41	1				2,200	....	26	30	28	98.7
" 3	27.0	2.59	0.1	35	3	.165	.084	49.2	1,700	55	65	....	60	96.5
" 4	28.0	2.65	0.1	26	5	3.9	1.9	51.3	3,300	....	....	35	35	98.9
" 5	25.0	2.68	0.2	25	5				1,500	24	16	....	20	98.7
" 6	27.0	2.67	0.2	16	5				1,000	24	31	18	24	97.6
" 7	25.0	2.74	0.2	14	3	.138	.090	34.9	450	23	27	23	24	94.7
" 8	23.0	2.66	0.2	11	3	3.3	2.1	36.4	600	37	20	13	23	96.2
" 9	23.0	2.68	0.2	16	2				850	19	31	19	23	97.3
" 10	22.0	2.61	0.3	12	3				1,500	11	21	....	16	98.9
" 11	23.0	2.62	0.6	8	0	.130	.080	38.5	1,600	....	....	21	21	98.7
" 12	21.0	2.59	1.1	8	0	2.8	1.7	39.2	550	10	14	14	13	97.6
" 13	21.0	2.65	1.3	8	2				220	13	10	15	13	94.1
" 14	21.0	2.52	1.4	10	2				275	12	13	25	17	93.8
" 15	22.0	2.64	1.4	12	2	.118	.066	44.1	2,600	80	14	21	38	98.5
" 16	22.0	2.80	1.4	11	6	2.0	1.4	30.0	2,100	28	19	12	20	99.0
" 17	21.0	2.74	1.4	12	0				1,400	11	15	....	13	99.1
" 18	22.0	2.68	1.3	18	1				4,200	....	....	20	20	99.5
" 19	22.0	2.67	1.1	33	0	.114	.068	40.4	2,200	17	32	26	25	98.9
" 20	21.0	....	†	11	0	2.2	1.3	41.0	1,900	31	....	....	80	95.8
" 21	22.0	2.56	0.2	10	0				1,400	18	19	22	20	98.6
" 22	23.0	2.58	0.2	16	1				1,200	23	19	15	19	98.4
" 23	22.0	2.56	0.2	27	1	.122	.070	42.6	5,000	8	14	17	13	99.7
" 24	23.0	2.61	0.2	30	0	2.1	1.3	38.1	4,200	11	16	....	13	99.7
" 25	22.0	0.91	0.2	15	0				.....	....	....	....	....	....

Permanently stopped September 25, 8:30 A. M.

* Closed inlet August 30, 5 P. M.; closed outlet August 31, 5:10 A. M. Opened inlet, after scraping, August 31, 11:20 A. M.; opened outlet August 31, 6:20 P. M.

† Closed inlet September 20, 12:05 A. M.; closed outlet September 20, 1:25 P. M. Opened inlet, after scraping, September 20, 7:20 P. M.; opened outlet September 21, 12:20 A. M.

APPENDIX III.

FILTER No. 20.

Results of Bacterial Analyses of Filter No. 20.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet	Hours	Cubic Feet.		
September 14	2.52 p. m.	1	3.2	120	....	.08	16	3	6,100
" 14	3.02 p. m.	1	3.2	120	2.4	.25	48	3	2,400
" 14	3.17 p. m.	1	3.2	120	2.4	.50	96	1	1,500
" 14	4.00 p. m.	1	3.2	120	....	1.22	222	4	1,600
" 14	5.00 p. m.	1	3.3	124	2.7	1.72	353	4	2,700
" 14	7.00 p. m.	1	3.5	131	3.1	3.72	764	4	23,600
" 14	9.00 p. m.	1	3.2	120	3.5	5.72	1,168	2	9,000
" 14	11.00 p. m.	1	3.2	120	4.3	7.72	1,551	5	15,000
" 14	12.00 p. m.	1	3.2	120	4.4	8.72	1,724	2	12,900
" 15	1.00 a. m.	1	3.2	120	5.6	9.72	1,903	5	9,100
" 15	3.00 a. m.	1	3.2	120	5.8	11.72	2,264	2	7,700
" 15	5.00 a. m.	1	3.2	120	6.4	13.72	2,634	2	5,700
" 15	7.00 a. m.	1	3.2	120	7.2	15.72	2,988	2	10,900
" 15	8.00 a. m.	1	3.2	120	7.6	16.72	3,278	....	8,300
" 15	9.11 a. m.	2	3.3	124	....	.07	14	3	2,900
" 15	9.21 a. m.	2	3.3	124	....	.24	46	3	2,700
" 15	9.37 a. m.	2	3.3	124	....	.51	98	2	7,200
" 15	11.00 a. m.	2	3.2	120	2.9	2.05	401	2	6,200
" 15	1.00 p. m.	2	3.3	124	3.7	4.05	772	2	4,100
" 15	3.00 p. m.	2	3.2	120	4.7	6.05	1,133	2	3,000
" 15	5.00 p. m.	2	3.1	116	5.6	8.05	1,519	2	3,700
" 15	7.00 p. m.	2	3.3	124	6.3	10.05	1,912	2	5,000
" 15	9.00 p. m.	2	3.1	116	7.1	12.05	2,276	2	7,200
" 15	11.00 p. m.	2	3.2	120	7.8	14.05	2,640	2	4,000
" 15	12.00 p. m.	2	3.2	120	8.1	15.05	2,819	....	1,100
" 16	1.15 a. m.	3	3.2	120	....	.08	16	3	4,300
" 16	1.45 a. m.	3	3.2	120	....	.58	111	2	1,800
" 16	3.00 a. m.	3	3.2	120	2.7	1.83	346	1	3,500
" 16	5.00 a. m.	3	3.2	120	3.1	3.83	732	1	1,200
" 16	7.00 a. m.	3	3.2	120	3.6	5.83	1,116	1	2,000
" 16	9.00 a. m.	3	3.2	120	4.4	7.83	1,488	1	4,100
" 16	11.00 a. m.	3	3.3	124	5.5	9.83	1,880	1	4,700
" 16	1.00 p. m.	3	3.3	124	6.1	11.83	2,286	1	2,000
" 16	3.00 p. m.	3	3.2	120	6.8	13.83	2,682	1	1,700
" 16	4.00 p. m.	3	3.2	120	7.4	14.83	2,880	....	1,400
" 16	5.00 p. m.	3	3.2	120	5.2	15.83	3,074	1	2,700
" 16	7.00 p. m.	3	3.2	120	6.2	17.83	3,457	1	4,100
" 16	9.00 p. m.	3	3.2	120	7.2	19.83	3,835	1	3,000
" 16	11.00 p. m.	3	3.2	120	8.0	21.83	4,205	1	1,400
" 17	1.00 a. m.	3	3.2	120	9.3	23.83	4,576	1	2,400
" 17	3.00 a. m.	3	3.2	120	9.8	25.83	4,850	1	2,500
" 17	4.20 a. m.	4	3.2	120	....	.08	16	2	1,400
" 17	4.45 a. m.	4	3.2	120	....	.50	96	2	2,500
" 17	6.00 a. m.	4	3.3	124	2.6	1.75	279	1	1,800
" 17	8.00 a. m.	4	3.2	120	3.0	3.75	755	1	1,600
" 17	10.00 a. m.	4	3.2	120	3.6	5.75	1,137	1	2,300
" 17	12.00 m.	4	3.2	120	4.1	7.75	1,521	1	1,700
" 17	2.00 p. m.	4	3.2	120	4.7	9.75	1,903	2	1,600
" 17	4.00 p. m.	4	3.2	120	5.4	11.75	2,183	2	1,100
" 17	6.00 p. m.	4	3.3	124	6.0	13.75	2,660	1	1,700

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
September 17	8.00 p. m.	4	3.2	120	6.8	15.75	3,050	2	lost
" 17	10.00 p. m.	4	3.2	120	7.5	17.75	3,439	2	4,000
" 17	12.00 p. m.	4	3.2	120	8.1	19.75	3,829	2	1,100
" 18	2.00 a. m.	4	3.2	120	8.6	21.75	4,197	2	2,200
" 18	4.00 a. m.	4	3.2	120	9.4	23.75	4,670	1	1,700
" 18	5.55 a. m.	5	3.2	120	....	.10	19	1	750
" 18	6.25 a. m.	5	3.2	120	....	.60	115	1	750
" 18	8.00 a. m.	5	3.2	120	2.8	2.18	338	1	750
" 18	10.00 a. m.	5	3.2	120	3.3	4.18	708	1	650
" 18	12.00 m.	5	3.2	120	3.7	6.18	1,076	2	600
" 18	2.00 p. m.	5	3.2	120	4.4	8.18	1,468	2	550
" 18	4.00 p. m.	5	3.2	120	4.8	10.18	1,820	1	1,000
" 18	6.00 p. m.	5	3.3	124	5.6	12.18	2,214	2	1,400
" 18	8.00 p. m.	5	3.2	120	6.1	14.18	2,607	1	1,100
" 18	10.00 p. m.	5	3.2	120	6.5	16.18	2,983	1	750
" 18	12.00 p. m.	5	3.3	124	7.2	18.18	3,366	1	750
" 19	2.00 a. m.	5	3.2	120	8.0	20.18	3,739	1	650
" 19	4.00 a. m.	5	3.2	120	8.5	22.18	4,124	1	450
" 19	6.00 a. m.	5	3.2	120	9.0	24.18	4,495	1	500
" 19	7.45 a. m.	6	3.2	120	....	.08	16	2	1,200
" 19	7.55 a. m.	6	3.2	120	....	.25	48	2	650
" 19	8.10 a. m	6	3.2	120	....	.50	96	2	600
" 19	10.00 a. m.	6	3.2	120	2.4	2.33	388	1	550
" 19	12.00 m.	6	3.2	120	3.5	4.33	774	1	400
" 19	2.00 p. m.	6	3.2	120	3.9	6.33	1,173	1	300
" 19	4.00 p. m.	6	3.3	124	4.5	8.33	1,569	1	350
" 19	6.00 p. m.	6	3.2	120	5.1	10.33	1,848	1	275
" 19	8.00 p. m.	6	3.3	124	5.5	12.33	2,330	1	250
" 19	10.00 p. m.	6	3.3	124	6.1	14.33	2,704	2	230
" 19	12.00 p. m.	6	3.2	120	6.5	16.33	3,074	1	210
" 20	2.00 a. m.	6	3.2	120	6.8	18.33	3,439	1	230
" 20	4.00 a. m.	6	3.2	120	7.1	20.33	3,823	1	210
" 20	6.00 a. m.	6	3.2	120	8.2	22.33	4,195	1	230
" 20	8.00 a. m.	6	3.2	120	8.9	24.33	4,573	1	250
" 20	10.00 a. m.	6	3.2	120	9.2	26.33	4,955	1	220
" 20	12.00 m.	6	3.2	120	9.8	28.33	5,314	1	120
" 20	1.19 p. m.	7	3.2	120	....	.08	16	2	600
" 20	1.30 p. m.	7	3.2	120	....	.27	52	2	475
" 20	1.45 p. m.	7	3.2	120	....	.52	100	2	350
" 20	3.00 p. m.	7	3.2	120	2.6	1.77	321	2	400
" 20	5.00 p. m.	7	3.2	120	3.1	3.77	727	1	230
" 20	7.00 p. m.	7	3.2	120	3.5	5.77	1,112	2	400
" 20	9.00 p. m.	7	3.2	120	3.7	7.77	1,492	2	450
" 20	11.00 p. m.	7	3.2	120	4.3	9.77	1,868	1	250
" 21	1.00 a. m.	7	3.2	120	4.8	11.77	2,251	1	190
" 21	3.00 a. m.	7	3.2	120	5.3	13.77	2,632	1	160
" 21	5.00 a. m.	7	3.2	120	6.0	15.77	3,015	1	150
" 21	7.00 a. m.	7	3.2	120	6.7	17.77	3,398	1	140
" 21	9.00 a. m.	7	3.2	120	7.1	19.77	3,805	1	300
" 21	11.00 a. m.	7	3.2	120	8.2	21.77	4,163	1	150
" 21	1.00 p. m.	7	3.2	120	9.1	23.77	4,435	1	95
" 21	3.00 p. m.	7	3.2	120	9.6	25.77	4,913	1	110
" 21	4.23 p. m.	8	3.3	124	....	.08	16	2	325
" 21	4.33 p. m.	8	3.3	124	....	.25	48	2	300
" 21	4.48 p. m.	8	3.3	124	....	.50	96	2	250
" 21	6.00 p. m.	8	3.2	120	2.8	1.70	351	1	400
" 21	8.00 p. m.	8	3.2	120	3.2	3.70	743	2	250
" 21	10.00 p. m.	8	3.2	120	3.4	5.70	1,138	1	250
" 21	12.00 p. m.	8	3.2	120	4.4	7.70	1,530	1	180
" 22	2.00 a. m.	8	3.2	120	4.9	9.70	1,913	1	110
" 22	4.00 a. m.	8	3.2	120	5.3	11.70	2,298	1	75
" 22	6.00 a. m.	8	3.2	120	6.1	13.70	2,677	1	65

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
September 22	8.00 a. m.	8	3.3	124	6.9	15.70	3,063	2	80
" 22	10.00 a. m.	8	3.2	120	7.4	17.70	3,451	1	70
" 22	12.00 m.	8	3.2	120	7.9	19.70	3,841	1	85
" 22	2.00 p. m.	8	3.3	124	8.9	21.70	4,211	2	130
" 22	4.15 p. m.	9	3.2	120	....	.08	16	2	300
" 22	4.25 p. m.	9	3.2	120	....	.25	48	2	230
" 22	4.45 p. m.	9	3.2	120	....	.58	108	1	170
" 22	6.00 p. m.	9	3.2	120	2.9	1.83	365	2	230
" 22	8.00 p. m.	9	3.2	120	3.6	3.83	758	1	120
" 22	10.00 p. m.	9	3.0	112	3.8	5.83	1,142	1	95
" 22	12.00 p. m.	9	3.2	120	4.7	7.83	1,522	1	120
" 23	2.00 a. m.	9	3.2	120	5.3	9.83	1,912	1	100
" 23	4.00 a. m.	9	3.2	120	6.0	11.83	2,298	1	130
" 23	6.00 a. m.	9	3.2	120	6.8	13.83	2,680	1	140
" 23	8.00 a. m.	9	3.3	124	7.7	15.83	3,038	1	180
" 23	10.00 a. m.	9	3.2	120	8.9	17.83	3,411	1	150
" 23	12.00 m.	9	3.2	120	9.8	19.83	3,682	1	160
" 23	5.50 p. m.	10	3.2	120	....	.08	16	2	475
" 23	6.00 p. m.	10	3.3	124	....	.25	48	2	550
" 23	6.15 p. m.	10	3.3	124	....	.50	96	1	550
" 23	8.00 p. m.	10	3.2	120	2.6	2.25	447	1	250
" 23	10.00 p. m.	10	3.2	120	3.0	4.25	836	2	275
" 23	12.00 p. m.	10	3.3	124	3.3	6.25	1,231	1	170
" 24	2.00 a. m.	10	3.2	120	3.5	8.25	1,622	1	150
" 24	4.00 a. m.	10	3.2	120	3.9	10.25	1,991	1	140
" 24	6.00 a. m.	10	3.2	120	4.1	12.25	2,380	1	160
" 24	8.00 a. m.	10	3.2	120	4.4	14.25	2,760	2	140
" 24	10.00 a. m.	10	3.5	131	5.6	16.25	3,198	1	180
" 24	12.00 m.	10	3.2	120	....	18.25	3,562	2	240
" 24	1.46 p. m.	11	3.2	120	....	.08	16	2	300
" 24	1.56 p. m.	11	3.2	120	....	.25	48	1	400
" 24	2.11 p. m.	11	3.2	120	....	.50	96	2	425
" 24	4.00 p. m.	11	3.3	124	2.8	2.32	478	1	450
" 24	6.00 p. m.	11	3.2	120	3.1	4.32	857	1	650
" 24	8.00 p. m.	11	3.2	120	3.5	6.32	1,246	1	325
" 24	10.00 p. m.	11	3.2	120	3.8	8.32	1,628	1	500
" 24	12.00 p. m.	11	3.3	124	4.4	10.32	2,011	1	475
" 25	2.00 a. m.	11	3.2	120	4.9	12.32	2,397	1	450
" 25	4.00 a. m.	11	3.2	120	5.1	14.32	2,783	1	200
" 25	6.00 a. m.	11	3.2	120	5.4	16.32	3,162	1	170
" 25	8.00 a. m.	11	3.3	124	6.0	18.32	3,549	1	180
" 25	10.00 a. m.	11	3.2	120	6.5	20.32	3,926	1	160
" 25	12.00 m.	11	3.2	120	7.4	22.32	4,301	1	160
" 25	2.00 p. m.	11	3.3	124	8.1	24.32	4,616	1	170
" 25	4.00 p. m.	11	3.2	120	8.4	26.32	5,022	1	140
" 25	6.00 p. m.	11	3.2	120	8.7	28.32	5,406	1	190
" 25	8.00 p. m.	11	3.2	120	9.0	30.32	5,871	1	120
" 25	10.00 p. m.	11	3.2	120	10.0	32.32	6,225	1	110
" 25	10.32 p. m.	12	3.2	120	....	.08	16	3	475
" 25	10.42 p. m.	12	3.2	120	....	.25	48	1	425
" 25	11.02 p. m.	12	3.3	124	....	.58	114	1	275
" 25	12.00 p. m.	12	3.3	124	2.8	1.55	300	1	120
" 26	2.00 a. m.	12	3.3	124	3.1	3.55	689	1	100
" 26	4.00 a. m.	12	3.2	120	3.7	5.55	1,076	1	95
" 26	6.00 a. m.	12	3.2	120	4.1	7.55	1,469	1	65
" 26	8.00 a. m.	12	3.2	120	4.4	9.55	1,755	1	70
" 26	10.00 a. m.	12	3.3	124	4.9	11.55	2,238	1	70
" 26	12.00 m.	12	3.3	124	5.7	13.55	2,630	1	50
" 26	2.00 p. m.	12	3.3	124	6.1	15.55	3,031	1	45
" 26	4.00 p. m.	12	3.2	120	2.9	17.55	3,305	1	150
" 26	6.00 p. m.	12	3.3	124	6.3	19.55	3,618	1	100
" 26	8.00 p. m.	12	3.2	120	6.9	21.55	3,993	1	275

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
September 26	10.00 p. m.	12	3.2	120	7.8	23.55	4,365	1	70
" 26	12.00 p. m.	12	3.2	120	8.2	25.55	4,732	1	33
" 27	2.00 a. m.	12	3.1	116	9.1	27.55	5,100	1	36
" 27	4.00 a. m.	12	3.1	116	9.5	29.55	5,477	1	18
" 27	6.00 a. m.	12	2.9	109	10.0	31.55	5,834	1	28
" 27	6.37 a. m.	13	3.2	120	....	.08	16	2	200
" 27	6.47 a. m.	13	3.2	120	....	.25	48	1	120
" 27	7 02 a. m.	13	3.2	120	....	.50	96	1	90
" 27	8.00 a. m.	13	3.2	120	2.7	1.47	287	1	65
" 27	10.00 a. m.	13	3.3	124	2.9	3.47	660	1	75
" 27	12.00 m.	13	3.3	124	3.7	5.47	1,029	1	42
" 27	2.00 p. m.	13	3.2	120	3.9	7.47	1,403	1	55
" 27	4.00 p. m.	13	3.3	124	4.3	9.47	1,793	1	50
" 27	6.00 p. m.	13	3.2	120	4.9	11.47	2,169	1	110
" 27	8.00 p. m.	13	3.2	120	5.6	13.14	2,564	1	70
" 27	10.00 p. m.	13	3.2	120	5.8	15.47	2,950	1	75
" 27	12.00 p. m.	13	3.3	124	6.5	17.47	3,340	1	75
" 28	2.00 a. m.	13	3.3	124	6.8	19.47	3,727	1	70
" 28	4.00 a. m.	13	3.2	120	7.1	21.47	4,106	1	75
" 28	6.00 a. m.	13	3.2	120	7.5	23.47	4,483	1	55
" 28	8.00 a. m.	13	3.3	124	8.0	25.47	4,851	1	75
" 28	10 00 a. m.	13	3.2	120	8.7	27.47	5,232	1	65
" 28	11.30 a. m.	13	3.2	120	....	28.97	5,513	....	60
" 28	2.00 p. m.	13	3.3	124	....	31.47	5,981	1	28
" 28	3.15 p. m.	13	3.0	112	....	32.71	6,203	....	41
" 28	7.42 p. m.	14	3.2	120	....	.08	16	2	150
" 28	7 52 p. m.	14	3.2	120	....	.25	48	1	140
" 28	8.07 p. m.	14	3.2	120	....	.50	96	2	110
" 28	9.00 p. m.	14	3.2	120	2.6	1.38	263	2	95
" 28	11.00 p. m.	14	3.3	124	3.0	3.38	653	1	50
" 29	1.00 a. m.	14	3.1	116	4.1	5.38	1,030	1	17
" 29	3.00 a. m.	14	3 2	120	4.6	7.38	1,413	1	23
" 29	5.00 a. m.	14	3.2	120	5.2	9.38	1,799	2	36
" 29	7.00 a. m.	14	3.2	120	5.7	11.38	2,184	2	12
" 29	9.00 a. m.	14	3.2	120	6.6	13.38	2,565	....	40
" 29	2.00 p. m.	14	3.4	127	7.0	14.81	2,878	2	45
" 29	4.00 p. m.	14	3.2	120	8.4	16.64	3,219	1	45
" 29	6.00 p. m.	14	3.3	124	8.9	18.64	3,627	2	80
" 29	8.00 p. m.	14	3.2	120	9.2	20.64	4,016	2	70
" 29	10.00 p. m.	14	3.2	120	10.0	22.64	4,387	2	30
" 29	10.32 p. m.	15	3.2	120	....	.08	16	1	130
" 29	10.42 p. m.	15	3.2	120	....	.25	48	2	160
" 29	10.57 p. m.	15	3.2	120	....	.50	96	2	140
" 29	12.00 p. m.	15	3.2	120	2.6	1.55	291	2	150
" 30	2.00 a. m.	15	3.3	124	3.0	3.55	679	2	100
" 30	4.00 a. m.	15	3.2	120	4.0	5.55	1,066	1	50
" 30	6.00 a. m.	15	3.2	120	4.9	7.55	1,447	1	35
" 30	8.00 a. m.	15	3.3	124	5.4	9.55	1,837	1	32
" 30	10.00 a. m.	15	3.4	127	6.1	11.55	2,236	1	36
" 30	12.00 m.	15	3.2	120	6.6	13.55	2,614	1	16
" 30	2.00 p. m.	15	3.2	120	7.2	15.55	2,993	1	18
" 30	4.00 p. m.	15	3.2	120	7.9	17.55	3,373	1	34
" 30	6.00 p. m.	15	3.2	120	8.4	19.55	3,753	1	190
" 30	8.00 p. m.	15	3.2	120	9.3	21.55	4,124	1	60
" 30	10.00 p. m.	15	3.2	120	9.9	23.55	4,489	1	85
" 30	10.35 p. m.	16	3.2	120	....	.08	16	2	200
" 30	10.45 p. m.	16	3.2	120	....	.25	48	1	95
" 30	11.00 p. m.	16	3.2	120	2.6	.50	96	1	70
" 30	12.00 p. m.	16	3.3	124	2.6	1.50	312	1	80
October 1	2.00 a. m.	16	3.2	120	3.5	3.50	673	2	200
" 1	4.00 a. m.	16	3.2	120	4 0	5.50	1,072	2	350
" 1	6.00 a. m.	16	3.2	120	4.4	7.50	1,472	1	275

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
October 1.....	8.00 a. m.	16	3.2	120	4.9	9.50	1,848	1	275
" 1.....	10.00 a. m.	16	3.3	124	5.9	11.50	2,231	1	425
" 1.....	12.00 m.	16	3.2	120	6.8	13.50	2,624	1	300
" 1.....	2.00 p. m.	16	3.2	120	7.6	15.50	3,030	1	9[illegible]
" 1.....	4.00 p. m.	16	3.2	120	8.6	17.50	3,408	1	8[illegible]
" 1.....	6.00 p. m.	16	3.2	120	8.9	19.50	3,787	1	9[illegible]
" 1.....	8.00 p. m.	16	3.2	120	9.5	21.50	4,166	1	15[illegible]
" 1.....	10.00 p. m.	16	3.2	120	10.0	23.50	4,526	1	19[illegible]
" 1.....	10.33 p. m.	17	3.2	120	....	.08	16	1	20[illegible]
" 1.....	10.43 p. m.	17	3.2	120	....	.25	48	1	19[illegible]
" 1.....	10.58 p. m.	17	3.2	120	....	.50	96	1	19[illegible]
" 1.....	12.00 p. m.	17	3.3	124	3.4	1.53	356	1	14[illegible]
" 2.....	2.00 a. m.	17	3.3	124	3.7	3.53	732	1	14[illegible]
" 2.....	4.00 a. m.	17	3.2	120	4.5	5.53	1,119	1	12[illegible]
" 2.....	6.00 a. m.	17	3.1	116	5.2	7.53	1,494	1	9[illegible]
" 2.....	8.00 a. m.	17	3.2	120	5.9	9.53	1,879	1	5[illegible]
" 2.....	10.00 a. m.	17	3.2	120	6.8	11.53	2,263	1	55
" 2.....	12.00 m.	17	3.2	120	7.4	13.53	2,646	1	6[illegible]
" 2.....	2.00 p. m.	17	3.2	120	8.0	15.53	2,928	1	2[illegible]
" 2.....	4.00 p. m.	17	3.2	120	9.0	17.53	3,396	1	2[illegible]
" 2.....	6.00 p. m.	17	3.1	116	9.9	19.53	3,757	1	8[illegible]
" 2.....	7.05 p. m.	18	3.1	116	....	.42	80	2	150
" 2.....	7.35 p. m.	18	3.2	120	....	.08	16	1	220
" 2.....	7.45 p. m.	18	3.2	120	....	.25	48	1	3[illegible]
" 2.....	8.00 p. m.	18	3.2	120	2.5	.50	98	2	9[illegible]
" 2.....	9.00 p. m.	18	3.2	120	2.7	1.50	296	2	5[illegible]
" 2.....	11.00 p. m.	18	3.2	120	3.4	3.50	683	1	5[illegible]
" 3.....	1.00 a. m.	18	3.2	120	4.1	5.50	959	1	5[illegible]
" 3.....	3.00 a. m.	18	3.3	124	4.9	7.50	1,452	1	24
" 3.....	5.00 a. m.	18	3.2	120	5.4	9.50	1,834	1	11
" 3.....	7.00 a. m.	18	3.2	120	6.1	11.50	2,216	2	17
" 3.....	9.00 a. m.	18	3.2	120	6.9	13.50	2,594	1	30
" 3.....	11.00 a. m.	18	3.2	120	7.6	15.50	3,072	2	36
" 3.....	1.00 p. m.	18	3.3	124	8.4	17.50	3,354	1	27
" 3.....	3.00 p. m.	18	3.2	120	9.0	19.50	3,731	1	55
" 3.....	5.00 p. m.	18	3.2	120	9.4	21.50	4,096	1	50
" 3	7.00 p. m.	18	3.2	120	9.8	23.50	4,461	2	65
" 3	8.33 p. m.	19	3.2	120	....	.08	16	1	170
" 3.....	8.43 p. m.	19	3.2	120	....	.25	48	2	110
" 3	8.58 p. m.	19	3.2	120	....	.50	96	1	95
" 3.....	10.00 p. m.	19	3.2	120	2.3	1.53	298	1	2[illegible]
" 3.....	12.00 p. m.	19	3.2	120	3.0	3.53	666	1	2[illegible]
" 4.....	2.00 a. m.	19	3.2	120	4.0	5.53	1,042	1	35
" 4.....	4.00 a. m.	19	3.2	120	4.6	7.53	1,431	1	30
" 4.....	6.00 a. m.	19	3.2	120	5.1	9.53	1,819	1	26
" 4.....	8.00 a. m.	19	3.3	124	6.0	11.53	2,205	1	4[illegible]
" 4.....	10.00 a. m.	19	3.4	127	6.9	13.53	2,609	1	46
" 4.....	12.00 m.	19	3.6	135	7.4	15.53	3,022	1	35
" 4.....	2.00 p. m.	19	3.2	120	7.9	17.53	3,412	2	27
" 4.....	4.00 p. m.	19	....	....	8.7	19.53	3,807	1	12
" 4.....	6.00 p. m.	19	3.1	116	9.0	21.53	4,195	1	22
" 4	8.00 p. m.	19	3.2	120	9.6	23.53	4,586	1	23
" 4.....	9.18 p. m.	19	....	....	....	24.83	4,818	2	10
" 4.....	9.45 p. m.	20	....	....	....	.08	16	1	110
" 4	9.55 p. m.	20	3.2	120	....	.25	48	1	60
" 4.....	10.10 p. m.	20	3.2	120	....	.50	96	1	28
" 4.....	11.00 p. m.	20	3.2	120	2.9	1.33	261	1	10
" 5.....	1.00 a. m.	20	3.3	124	3.1	3.33	650	1	10
" 5.....	3.00 a. m.	20	3.3	124	3.6	5.33	1,038	1	9
" 5.....	5.00 a. m.	20	3.3	124	4.3	7.33	1,429	1	7
" 5.....	7.00 a. m.	20	3.2	120	4.7	9.33	1,613	2	13
" 5.....	9.00 a. m.	20	3.2	120	5.5	11.33	2,184	2	8

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
October 5	11.00 a. m.	20	3.6	135	5.8	13.08	2,487	1	27
" 5	1.00 p. m.	20	3.2	120	6.9	15.08	2,873	1	40
" 5	3.00 p. m.	20	3.3	124	7.5	17.08	3,275	1	60
" 5	5.00 p. m.	20	3.2	120	8.1	19.08	3,657	1	85
" 5	7.00 p. m.	20	3.2	120	8.7	21.08	4,044	1	39
" 5	9.00 p. m.	20	3.2	120	9.4	23.08	4,424	1	19
" 5	10.07 p. m.	20	....	....	....	24.19	4,616	1	24
" 5	10.33 p. m.	21	3.2	120	....	.08	16	2	100
" 5	10.43 p. m.	21	3.2	120	....	.25	48	1	70
" 5	10.58 p. m.	21	3.2	120	....	.50	96	1	40
" 5	12.00 p. m.	21	3.3	124	2.7	1.53	203	1	20
" 6	2.00 a. m.	21	3.3	124	3.4	3.53	601	1	19
" 6	4.00 a. m.	21	3.2	120	3.7	5.53	986	1	20
" 6	6.00 a. m.	21	3.2	120	4.3	7.53	1,365	1	19
" 6	8.00 a. m.	21	3.2	120	4.8	9.53	1,752	1	12
" 6	10.00 a. m.	21	3.3	124	5.7	11.53	2,140	1	14
" 6	12.00 m.	21	3.3	124	6.3	13.53	2,530	1	16
" 6	2.00 p. m.	21	3.4	128	7.0	15.53	2,947	1	21
" 6	4.00 p. m.	21	3.3	124	7.8	17.53	3,340	1	7
" 6	6.00 p. m.	21	3.2	120	8.2	19.53	3,723	1	23
" 6	8.00 p m.	21	3.4	128	8.9	21.53	4,113	1	11
" 6	10.00 p. m.	21	3.3	124	9.4	23.53	4,493	1	20
" 6	12.00 p. m.	21	3.1	116	9.7	25.53	4,857	1	9
" 7	12.55 a. m.	21	3.2	120	....	26.45	5,026	1	100
" 7	1.33 a. m.	22	3.2	120	....	.08	16	1	100
" 7	1.43 a. m.	22	3.2	120	....	.25	48	1	29
" 7	1.58 a. m.	22	3.2	120	....	.50	96	1	11
" 7	3.00 a. m.	22	3.2	120	2.6	1.53	301	1	16
" 7	5.00 a. m.	22	3.3	124	3.5	3.53	698	1	18
" 7	7.00 a. m.	22	3.3	124	4.0	5.53	1,086	1	8
" 7	9.00 a. m.	22	3.3	124	4.9	7.53	1,480	1	15
" 7	11.00 a. m.	22	3.3	124	5.6	9.53	1,875	1	12
" 7	1.00 p. m.	22	3.4	128	6.7	11.53	2,268	1	18
" 7	3.00 p. m.	22	3.3	124	7.3	13.53	2,669	1	16
" 7	5.00 p. m.	22	3.2	120	8.1	15.53	3,054	1	11
" 7	7.00 p. m.	22	3.2	120	9.0	17.53	3,442	1	10
" 7	9.00 p. m.	22	3.2	120	10.0	19.53	3,823	1	4
" 7	9.10 p. m.	22	3.2	120	....	19.70	3,854	1	10
" 8	2.15 p. m.	23	3.1	116	....	.08	16	1	75
" 8	2.25 p. m.	23	3.4	128	....	.25	51	1	55
" 8	2.40 p. m.	23	3.3	124	....	.50	99	1	33
" 8	4.00 p. m.	23	3.0	112	3.6	1.83	376	1	21
" 8	6.00 p. m.	23	3.2	120	4.0	3.83	763	1	70
" 8	8.00 p. m.	23	3.3	124	4.9	5.83	1,160	1	50
" 8	10.00 p. m.	23	3.2	120	5.3	7.83	1,553	1	42
" 8	12.00 p. m.	23	3.2	120	5.9	9.83	1,837	1	30
" 9	2.00 a. m.	23	3.3	124	6.8	11.83	2,325	1	12
" 9	4.00 a. m.	23	3.2	120	7.1	13.83	2,705	1	5
" 9	6.00 a. m.	23	3.2	120	8.1	15.83	3,075	1	7
" 9	8.00 a. m.	23	3.2	120	9.2	17.83	3,453	1	9
" 9	10 16 a. m.	24	3.2	120	....	.08	16	1	18
" 9	10.27 a. m.	24	3.3	124	....	.25	48	1	34
" 9	10.42 a. m.	24	3.3	124	....	.50	99	1	13
" 9	12.00 m.	24	3.5	131	2.6	1.82	360	1	50
" 9	2.00 p. m.	24	3.3	124	3.4	3.82	749	1	20
" 9	4.00 p. m.	24	3.4	128	4.1	5.82	1,149	1	20
" 9	6.00 p. m.	24	3.2	120	4.2	7.82	1,530	1	33
" 9	8.00 p. m.	24	3.0	112	5.0	9.82	1,917	1	34
" 9	10.00 p. m.	24	3.2	120	5.9	11.82	2,303	1	9
" 9	12.00 p. m.	24	3 3	124	6.2	13.82	2,707	1	11
" 10	2.00 a. m.	24	3.2	120	6.8	15.82	3,099	1	18
" 10	4.00 a. m.	24	3.2	120	7 1	17.82	3,480	1	9

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.			Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.		Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
October	10.....	6.00 a. m.	24	3.2	120	7.4	19.82	3,859	1	13
"	10.....	8.00 a. m.	24	3.2	120	8.3	21.82	4,231	1	9
"	10.....	10.00 a. m.	24	3.3	124	8.8	23.82	4,624	1	10
"	10.....	12.00 m.	24	3.3	124	9.3	25.82	5,009	1	25
"	10.....	2.00 p. m.	24	3.2	120	9.9	27.82	5,383	1	21
"	10.....	2.38 p. m.	24	3.2	120	....	28.39	5,492	1	100
"	10.....	2.53 p. m.	24	3.3	124	....	28.64	5,523	1	55
"	10.....	7.13 p. m.	25	....	....	....	.08	16	1	41
"	10.....	7.23 p. m.	25	....	....	....	.25	48	1	50
"	10.....	7.38 p. m.	25	....	....	....	.50	96	1	65
"	10.....	9.00 p. m.	25	3.2	120	3.0	1.87	367	1	65
"	10.....	11.00 p. m.	25	3.2	120	3.6	3.87	747	1	80
"	11.....	1.00 a. m.	25	3.2	120	4.2	5.87	1,132	1	24
"	11.....	3.00 a. m.	25	3.3	124	4.9	7.87	1,516	1	17
"	11.....	5.00 a. m.	25	3.4	120	5.4	9.87	1,907	1	22
"	11.....	7.00 a. m.	25	3.2	120	6.2	11.87	2,283	1	16
"	11.....	9.00 a. m.	25	3.4	128	7.0	13.87	2,669	1	22
"	11.....	11.00 a. m.	25	3.3	124	7.6	15.87	3,053	1	25
"	11.....	1.00 p. m.	25	3.2	120	8.5	17.87	3,449	1	16
"	11.....	3.00 p. m.	25	3.3	124	9.0	19.87	3,845	1	15
"	11.....	5.00 p. m.	25	3.2	120	9 6	21.87	4,232	1	19
"	11.....	7.00 p. m.	25	3.2	120	10.0	23.87	4,590	1	11
"	11.....	7.08 p. m.	25	3.2	120	....	23.94	4,597	1	27
"	11.....	7.18 p. m.	25	3.2	120	....	24.11	4,610	1	20
"	12.....	2 55 a. m.	26	3.2	120	....	.08	16	1	50
"	12.....	3.05 a. m.	26	3.2	120	....	.25	48	1	32
"	12.....	3.20 a. m.	26	3.2	120	....	.50	96	1	20
"	12.....	5.00 a. m.	26	3.2	120	2.8	2.17	419	1	19
"	12.....	7.00 a. m.	26	3.3	124	3.4	4.17	810	1	13
"	12.....	9.00 a. m.	26	3.3	124	3.8	6.17	1,205	1	9
"	12.....	11.00 a. m.	26	3.3	124	4.8	8.17	1,627	1	18
"	12.....	1.00 p. m.	26	3.4	128	4.3	10.17	2,081	1	13
"	12.....	3.00 p. m.	26	3.3	124	5.3	12.17	2,468	1	10
"	12.....	5.00 p. m.	26	3.3	124	5.5	14.17	2,881	1	6
"	12.....	7.00 p. m.	26	3.2	120	6 0	16.17	3,256	1	7
"	12.....	9.00 p. m.	26	3.1	116	6.1	18.17	3,634	1	7
"	12.....	11.00 p. m.	26	3.2	120	6.9	20.17	4,074	1	10
"	13.....	1.00 a. m.	26	3.2	120	7.2	22.17	4,405	1	10
"	13.....	3.00 a. m.	26	3.1	116	7.8	24.17	4,787	1	9
"	13.....	5.00 a. m.	26	3.2	120	8.3	26.17	5,176	1	7
"	13.....	7.00 a. m.	26	3.3	124	8.6	28.17	5,562	1	21
"	13.....	9.00 a. m.	26	3.3	124	9.2	30.17	5,949	1	13
"	13.....	11.00 a. m.	26	3.2	120	9.6	32.17	6,339	1	9
"	13.....	1.00 p. m.	26	3.2	120	10.0	34.17	6,720	1	5
"	13.....	1.10 p. m.	26	3.2	120	....	34.27	6,747	1	16
"	13.....	1.20 p. m.	26	3.2	120	....	34.44	6,774	1	5
"	13.....	2.03 p. m	26	3.2	120	10.0	35.15	6,898	1	8
"	13.....	9.30 p. m.	27	3.2	120	....	.08	16	1	80
"	13.....	9.40 p. m.	27	3.2	120	....	.25	48	1	12
"	13.....	9.55 p. m.	27	3.3	124	....	.50	96	1	14
"	13.....	11.00 p. m.	27	3.1	116	2.8	1.58	304	1	41
"	14.....	1.00 a. m.	27	3.2	120	3.2	3.58	695	1	28
"	14.....	3.00 a. m.	27	3.3	124	3.8	5.58	1,083	1	35
"	14.....	5.00 a. m.	27	3.3	124	4.5	7.58	1,472	1	45
"	14.....	7.00 a. m.	27	3.2	120	4.8	9.58	1,865	1	43
"	14.....	9.00 a. m.	27	3.3	124	5.3	11.58	2,259	1	49
"	14.....	11.00 a. m.	27	3.4	128	6.0	13.58	2,664	1	29
"	14.....	1.00 p. m.	27	3.2	120	6.2	15.58	3,061	1	44
"	14.....	3.00 p. m.	27	3.3	124	7.2	17.58	3,465	1	55
"	14.....	5.00 p. m.	27	3.3	124	7.6	19.58	3,878	1	7
"	14	7.00 p. m.	27	3.2	120	7.8	21.58	4,267	1	26
"	14.....	9.00 p. m.	27	3.2	120	8.1	23.58	4,639	1	14

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
October 14	11.00 p. m.	27	3.1	116	9.0	25.58	5,001	1	14
" 15	1.00 a. m.	27	3.2	120	9.2	27.58	5,395	1	23
" 15	3.00 a. m.	27	3.1	116	9.8	29.58	5,775	1	7
" 15	4.08 a. m.	27	....	....	....	30.75	5,973	1	95
" 15	4.23 a. m.	27	....	....	....	31.00	6,021	1	10
" 15	5.00 a. m.	27	3.2	120	9.1	31.50	6,143	1	7
" 15	11.55 a. m.	28	3.2	120	....	.08	16	1	33
" 15	12.05 p. m.	28	3.3	124	....	.25	48	1	28
" 15	12.30 p. m.	28	3.3	124	....	.60	142	1	55
" 15	2.00 p. m.	28	3.2	120	3.7	2.17	328	1	29
" 15	4.00 p. m.	28	....	....	4.6	4.17	804	1	2
" 15	6.00 p. m.	28	3.2	120	5 4	6.17	1,182	1	24
" 15	8.00 p. m.	28	3.2	120	6.4	8.17	1,564	1	16
" 15	10.00 p. m.	28	3.2	120	7.2	10.17	1,941	1	14
" 15	12.00 p. m.	28	3.2	120	8.7	12.17	2,215	1	10
" 16	2.00 a. m.	28	3.1	116	9.2	14.17	2,699	1	12
" 16	4.00 a. m.	28	3.0	112	9.6	16.17	3,064	1	32
" 16	4.18 a. m.	28	3.2	120	....	16.40	3,109	1 ag	itated11
" 16	7.24 a. m.	29	3.2	120	....	.08	16	1	40
" 16	7.34 a. m.	29	3.2	120	....	.25	48	1	33
" 16	7.49 a. m.	29	3.2	120	....	.50	96	1	33
" 16	9.00 a. m.	29	3.2	120	3 2	1.68	313	1	23
" 16	11.00 a. m.	29	3.3	124	4.0	3.68	696	1	22
" 16	1.00 p. m.	29	3.3	124	4.6	5.68	1,088	1	43
" 16	3.00 p. m.	29	3.3	124	5.4	7.68	1,483	1	20
" 16	5.00 p. m.	29	3.3	124	6.0	9.68	1,884	1	21
" 16	7.00 p. m.	29	3.3	124	6.6	11 68	2,263	1	25
" 16	9.00 p. m.	29	3.2	120	7.0	13.68	2,661	1	21
" 16	11.00 p. m.	29	3.2	120	7.5	15.68	3,033	1	20
" 17	1.00 a. m.	29	3.2	120	7.6	17.68	3,401	1	31
" 17	3.00 a. m.	29	3.3	124	8.6	19.68	3,777	1	50
" 17	5.00 a. m.	29	3.2	120	9.5	21.68	4,165	1	70
" 17	9.30 a. m.	30	3.2	120	....	.08	16	1	49
" 17	9.40 a. m.	30	3.2	120	....	.25	48	1	31
" 17	9.55 a. m.	30	3.3	124	....	.50	96	1	10
" 17	11.00 a. m.	30	3.2	120	3.3	1.58	321	1	6
" 17	1.00 p. m.	30	3.3	124	4.0	3.58	629	1	10
" 17	3.00 p. m.	30	3.3	124	4.5	5.58	1,125	1	11
" 17	5.00 p. m.	30	3.2	120	4.9	7.58	1,499	1	6
" 17	7.00 p. m.	30	3.3	124	5.6	9.58	1,879	1	6
" 17	9.00 p. m.	30	3.2	120	6.4	11.58	2,257	1	7
" 17	11.00 p. m.	30	3.2	120	7.9	13.58	2,632	1	6
" 18	1.00 a. m.	30	3.2	120	8.0	15.58	3,028	1	8
" 18	3.00 a. m.	30	3.2	120	8.8	17.58	3,415	1	12
" 18	5.00 a. m.	30	3.2	120	9.5	19.58	3,796	1	75
" 18	7.00 a. m.	30	3.0	120	10.0	21.58	4,165	1	85
" 18	7.08 a. m.	30	3.2	120	....	21.64	4,176	2	220
" 18	7.23 a. m.	30	3.2	120	....	21.90	4,216	1	95
" 18	11.30 a. m.	31	3.5	181	....	.06	17	1	49
" 18	11.40 a. m.	31	3.3	124	....	.25	49	1	44
" 18	11.55 a. m.	31	3.3	124	....	.55	99	1	22
" 18	1.00 p. m.	31	3.2	120	3.5	1.58	303	1	11
" 18	3.00 p. m.	31	3.3	124	4.1	3.58	707	1	15
" 18	5.00 p. m.	31	3.2	120	4.8	5.58	1,094	1	15
" 18	7.00 p. m.	31	3.3	124	5.6	7.58	1,481	1	4
" 18	9.00 p. m.	31	3.2	120	6.0	9.58	1,847	1	4
" 18	11.00 p. m.	31	3.0	112	8.2	11.58	2,197	1	70
" 19	1.00 a. m.	31	3.2	120	9.3	13.58	2,581	1	3
" 19	3.00 a. m.	31	3.2	120	9.8	15.58	2,963	1	31
" 19	3.32 a. m.	31	....	....	....	16.05	3,047	1	12
" 19	3.47 a. m.	31	....	....	....	16.30	3,092	1	5
19	5.00 a. m.	31	3.1	116	9.3	17.51	3,323	1	10

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
October 19	1.55 p. m.	32	3.4	128	....	.12	24	1	45
" 19	2.08 p. m.	32	3.3	124	....	.33	64	1	17
" 19	2.23 p. m.	32	3.3	124	....	.58	115	1	12
" 19	4.00 p. m.	32	3.2	120	2.9	2.20	407	1	19
" 19	6.00 p. m.	32	3.2	120	3.5	4.20	794	1	11
" 19	8.00 p. m.	32	3.2	120	3.9	6.20	1,180	1	12
" 19	10.00 p. m.	32	3.2	120	4.2	8.20	1,562	1	8
" 19	12.00 p. m.	32	3.4	128	5.3	10.20	1,964	1	14
" 20	2.00 a. m.	32	3.2	120	5.2	12.20	2,358	1	41
" 20	4.00 a. m.	32	3.2	120	5.7	14.20	2,754	1	55
" 20	6.00 a. m.	32	3.2	120	6.1	16.20	3,146	1	70
" 20	8.00 a. m.	32	3.3	124	6.4	18.20	3,543	1	60
" 20	10.00 a. m.	32	3.4	128	7.2	20.20	3,943	1	50
" 20	12.00 m.	32	3.2	120	7.3	22.20	4,339	1	33
" 20	2.00 p. m.	32	3.2	120	7.9	24.20	4,714	1	65
" 20	4.00 p. m.	32	....	....	8.8	26.20	5,118	1	70
" 20	6.00 p. m.	32	3.3	124	9.1	28.20	5,515	1	6
" 20	8.00 p. m.	32	3.2	120	9.2	30.20	5,897	1	32
" 20	10.00 p. m.	32	3.2	120	10.0	32.20	6,268	1	31
" 20	10.08 p. m.	32	3.2	120	....	32.27	6,281	1	42
" 20	10.18 p. m.	32	3.2	120	....	32.43	6,326	1	26
" 21	6.58 a. m.	33	3.2	120	....	.08	16	1	25
" 21	7.08 a. m.	33	3.2	120	....	.25	48	1	40
" 21	7.23 a. m.	33	3.2	120	....	.50	96	1	33
" 21	9.00 a. m.	33	3.2	120	3.5	2.12	407	1	20
" 21	11.00 a. m.	33	3.3	124	4.0	4.12	816	1	43
" 21	1.00 p. m.	33	3.3	124	4.5	6.12	1,219	1	41
" 21	3.00 p. m.	33	3.2	120	4.9	8.12	1,617	1	35
" 21	5.00 p. m.	33	3.2	120	5.5	10.12	2,001	1	24
" 21	7.00 p. m.	33	3.2	120	5.8	12.12	2,394	1	45
" 21	9.00 p. m.	33	3.2	120	6.5	14.12	2,771	1	45
" 21	11.00 p. m.	33	3.1	116	6.8	16.12	3,151	1	30
" 22	1.00 a. m.	33	3.2	120	7.8	18.12	3,543	1	35
" 22	3.00 a. m.	33	3.2	120	8.2	20.12	3,925	1	38
" 22	5.00 a. m.	33	3.2	120	8.9	22.12	4,312	1	15
" 22	7.00 a. m.	33	3.2	120	9.4	24.12	4,693	1	24
" 22	9.00 a. m.	33	3.2	120	9.8	26.12	5,071	1	18
" 22	9.59 a. m.	33	3.2	120	....	26.20	5,215	1	40
" 22	10.09 a. m.	33	3.2	120	....	26.37	5,277	1	65
" 22	10.59 a. m.	33	3.2	120	....	27.97	5,431	1	35
" 22	11.00 a. m.	33	3.2	120	7.7	28.00	5,434	1	40
" 22	11.09 a. m.	33	3.2	120	....	28.15	5,463	1	41
" 22	12.44 p. m.	33	3.2	120	....	29.67	5,743	1	120
" 22	12.54 p. m.	33	3.2	120	....	29.83	5,775	1	55
" 22	1.05 p. m.	33	3.2	120	....	30.00	5,799	1	45
" 22	7.15 p. m.	34	3.3	124	....	.08	16	1	5
" 22	7.25 p. m.	34	3.2	120	....	.25	48	1	6
" 22	7.40 p. m.	34	3.2	120	....	.50	96	1	15
" 22	9.00 p. m.	34	3.2	120	....	1.83	350	1	37
" 22	11.00 p. m.	34	3.2	120	4.2	3.83	730	1	19
" 23	1.00 a. m.	34	3.4	128	5.1	5.83	1,123	1	16
" 23	3.00 a. m.	34	3.2	120	5.7	7.83	1,516	1	13
" 23	5.00 a. m.	34	3.2	120	6.4	9.83	1,902	1	12
" 23	7.00 a. m.	34	3.3	124	6.9	11.83	2,292	1	8
" 23	9.00 a. m.	34	3.2	120	7.5	13.83	2,679	1	7
" 23	11.00 a. m.	34	3.1	116	9.2	15.83	3,050	1	34
" 23	1.00 p. m.	34	....	....	7.8	17.78	3,436	1	300
" 23	1.10 p. m.	34	3.2	120	....	17.95	3,468	1	110
" 23	1.25 p. m.	34	....	....	....	18.20	3,516	1	160
" 23	3.00 p. m.	34	....	....	7.2	19.78	3,838	1	130
" 23	5.00 p. m.	34	3.2	120	8.5	21.78	4,237	1	95
" 23	6.10 p. m.	34	....	....	....	21.90	4,446	2	250

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
October 23	6.25 p. m.	34	....	....	....	22.15	4,481	1	70
" 23	7.00 p. m.	34	3.2	120	9.8	23.68	4,608	1	60
" 23	9.00 p. m.	34	3.2	120	10.0	25.68	4,992	1	60
" 24	1.45 a. m.	35	3.2	120	....	.08	16	1	29
" 24	1.55 a. m.	35	3.2	120	....	.25	48	1	22
" 24	2.10 a. m.	35	3.2	120	....	.50	96	1	11
" 24	4.00 a. m.	35	3.2	120	3.5	2 33	446	1	14
" 24	6.00 a. m.	35	3.2	120	4.3	4.33	829	1	13
" 24	8.00 a. m.	35	3.2	120	5.4	6.33	1,208	1	8
" 24	10.00 a. m.	35	3.2	120	6.4	8.33	1,586	1	14
" 24	12 00 m.	35	3.2	120	7.4	10.33	1,957	1	12
" 24	2.00 p. m.	35	3.2	120	8.4	12.33	2,347	1	14
" 24	4.00 p. m.	35	3.2	120	8.7	14.33	2,731	1	14
" 24	6.00 p. m.	35	3.2	120	10.0	16.33	3,111	1	12
" 24	6.10 p. m.	35	....	....	....	16.46	3,137	1	9
" 24	6.25 p. m.	35	....	....	....	16.71	3,185	1	13
" 24	8.00 p. m.	35	3.0	112	10.1	18.20	3,359	1	9
" 24	9.30 p. m.	36	3.2	120	....	.08	16	1	26
" 24	9.40 p. m.	36	3.2	120	....	.25	48	1	19
" 24	9.55 p. m.	36	3.2	120	....	.50	96	1	17
" 24	11.00 p. m.	36	3.2	120	3.1	1.58	114	1	14
" 25	1.00 a. m.	36	3.3	124	4.1	3.58	693	1	12
" 25	3.00 a. m.	36	3.2	120	4.6	5.58	1,082	2	9
" 25	5.00 a. m.	36	3.2	120	5.0	7.58	1,463	1	13
" 25	7.00 a. m.	36	3.2	120	6.6	9.58	1,839	1	22
" 25	9.00 a. m.	36	3.3	124	7.5	11.58	2,248	1	13
" 25	11.00 a. m.	36	3.4	128	7.8	13.58	2,645	1	9
" 25	1.00 p. m.	36	3.3	124	8.5	15.58	3,020	1	13
" 25	3.00 p. m.	36	3.2	120	9.8	17.58	3,390	1	9
" 25	3.44 p. m.	36	3.2	120	....	18.28	3,524	1	26
" 25	3.54 p. m.	36	3.2	120	....	18.45	3,556	1	16
" 25	5.00 p. m.	36	3.4	128	10.0	19.55	3,801	1	16
" 25	5.10 p. m.	36	....	....	....	19.70	3,826	1	23
" 25	5.25 p. m.	36	....	....	10.0	19.93	3,874	1	15
" 26	1.17 a. m.	37	3.2	120	2.9	.08	16	1	75
" 26	1.27 a. m.	37	3.2	120	....	.25	48	1	95
" 26	1.42 a. m.	37	3.2	120	....	.50	96	1	100
" 26	3.00 a. m.	37	3.2	120	3.3	1.80	344	1	50
" 26	5.00 a. m.	37	3.2	120	3.6	3.80	728	1	48
" 26	7.00 a. m.	37	3.2	120	4.5	5.80	1,107	1	33
" 26	9.00 a. m.	37	3.2	120	4.6	7.80	1,503	1	43
" 26	11.00 a. m.	37	3.3	124	5.2	9.80	1,881	1	50
" 26	1.00 p. m.	37	3.2	120	5.6	11.80	2,272	1	29
" 26	3.00 p. m.	37	3.3	124	6.5	13.80	2,683	1	26
" 26	5.00 p. m.	37	3.2	120	6.8	15.80	3,063	1	27
" 26	7.00 p. m.	37	3.4	128	7.6	17.80	3,456	1	42
" 26	9.00 p. m.	37	3.4	128	7.7	19.80	3,856	1	22
" 26	11.00 p. m.	37	3.2	120	8.6	21.80	4,236	1	39
" 27	1.00 a. m.	37	3.2	120	8.9	23.80	4,622	1	38
" 27	10.17 a. m.	38	3.4	128	....	.08	17	1	90
" 27	10.27 a. m.	38	3.2	120	....	.25	48	1	110
" 27	10.42 a. m.	38	3.2	120	....	.50	96	1	85
" 27	12.00 m.	38	3.3	124	3.5	1.80	290	1	100
" 27	12.48 p. m.	39	3.2	120	....	.08	16	1	90
" 27	12.58 p. m.	39	3.2	120	....	.25	48	1	120
" 27	1.12 p. m.	39	3.2	120	2.9	.50	96	2	190
" 27	1.43 p. m.	39	3.2	120	....	1.00	192	2	120
" 27	2.13 p. m.	39	3.3	124	....	1.50	285	1	65
" 27	2.43 p. m.	39	3.3	124	3.5	2.00	371	1	65
" 27	3.52 p. m.	40	3.2	120	....	.17	33	1	46
" 27	4.02 p. m.	40	3.2	120	2.9	.33	64	1	75
" 27	4.17 p. m.	40	3.2	120	....	58	83	1	65

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
October 27	4.47 p. m.	40	....	....	....	1.08	178	1	47
" 27	5.12 p. m.	40	....	....	3.5	1.50	258	1	45
" 27	5.42 p. m.	40	3.2	120	....	2.00	368	1	21
" 27	6.35 p. m.	41	3.2	120	....	.08	16	2	55
" 27	6.45 p. m.	41	3.2	120	....	.25	48	1	35
" 27	7.00 p. m.	41	3.3	124	3.1	.50	96	1	34
" 27	7.30 p. m.	41	3.2	120	....	1.00	192	1	9
" 27	8.00 p. m.	41	3.2	120	3.5	1.50	288	2	18
" 27	8.30 p. m.	41	3.2	120	....	2.00	384	1	13
" 28	4.10 a. m.	42	3.2	120	....	.08	16	2	75
" 28	4.20 a. m.	42	3.2	120	....	.25	48	1	60
" 28	4.35 a. m.	42	3.2	120	....	.50	96	2	65
" 28	5.05 a. m.	42	3.2	120	3.3	1.00	265	2	90
" 28	5.35 a. m.	42	3.2	120	....	1.50	350	2	85
" 28	6.10 a. m.	42	3.2	120	3.6	2.00	436	2	60
" 28	8.00 a. m.	42	3.2	120	3.9	3.83	837	1	90
" 28	9.00 a. m.	42	3.2	120	4.0	4.83	1,035	2	50
" 28	10.00 a. m.	42	3.3	124	4.0	5.83	1,233	1	46
" 28	11.00 a. m.	42	3.2	120	4.1	6.83	1,422	1	34
" 28	11.31 a. m.	43	3.4	128	....	.08	17	1	50
" 28	11.41 a. m.	43	3.3	124	....	.25	49	1	43
" 28	11.56 a. m.	43	3.2	120	2.9	.50	96	1	32
" 28	12.26 p. m.	43	3.3	124	....	1.00	213	1	23
" 28	12.56 p. m.	43	3.2	120	3.2	1.50	322	1	23
" 28	1.26 p. m.	43	3.2	120	3.6	2.00	421	1	36
" 28	2.26 p. m.	43	3.3	124	3.6	3.00	623	1	23
" 28	3.26 p. m.	43	3.3	124	3.7	4.00	827	1	18
" 28	4.26 p. m.	43	3.2	120	....	5.00	1,019	1	14
" 28	5.26 p. m.	43	3.2	120	....	6.00	1,211	1	13
" 28	7.00 p. m.	43	3.2	120	3.6	7.57	1,540	1	10
" 28	9.00 p. m.	43	3.3	124	4.4	9.57	1,934	1	9
" 28	11.00 p. m.	43	3.2	120	5.7	11.57	2,321	1	10
" 29	12.07 a. m.	44	3.2	120	....	0.08	16	1	90
" 29	12.17 a. m.	44	3.2	120	....	0.25	48	1	25
" 29	12.32 a. m.	44	3.2	120	2.9	0.50	96	1	25
" 29	2.00 a. m.	44	3.2	120	3.2	1.97	362	1	17
" 29	4.00 a. m.	44	3.3	124	3.7	3.97	752	1	21
" 29	6.00 a. m.	44	3.2	120	4.1	5.97	1,137	1	34
" 29	8.00 a. m.	44	3.2	120	4.4	7.97	1,523	1	47
" 29	10.00 a. m.	44	3.2	120	4.8	9.97	1,907	1	19
" 29	12.00 m.	44	3.4	128	5.3	11.97	2,316	1	33
" 29	2.00 p. m.	44	3.3	124	5.7	13.97	2,702	1	29
" 29	4.00 p. m.	44	3.2	120	5.9	15.97	3,092	1	29
" 29	6.00 p. m.	44	3.4	128	6.6	17.97	3,488	1	30
" 29	8.00 p. m.	44	3.2	120	6.7	19.97	3,882	1	36
" 29	10.00 p. m.	44	3.3	124	7.1	21.97	4,277	1	34
" 29	12.00 p. m.	44	3.2	120	7.5	23.97	4,664	1	42
" 30	2.00 a. m.	44	3.2	120	7.9	25.97	5,049	1	75
" 30	4.00 a. m.	44	3.2	120	8.3	27.97	5,432	2	61
" 30	6.00 a. m.	44	3.2	120	8.7	29.97	5,811	1	95
" 30	8.00 a. m.	44	3.2	120	9.0	31.97	6,192	1	63
" 30	10.00 a. m.	44	3.2	120	9.2	33.97	6,562	1	75
" 30	7.35 p. m.	45	3.2	120	....	.08	16	1	48
30	7.45 p. m.	45	3.2	120	....	.25	48	1	38
" 30	8.00 p. m.	45	3.2	120	3.0	.50	96	1	19
" 30	9.00 p. m.	45	3.0	112	3.4	1.50	275	1	26
" 30	11.00 p. m.	45	3.2	120	4.4	3.50	647	4	33
" 31	1.00 a. m.	45	3.2	120	5.6	5.50	1,032	2	220
" 31	3.00 a. m.	45	3.2	120	6.6	7.50	1,417	4	275
" 31	5.00 a. m.	45	3.2	120	7.6	9.50	1,799	1	350
" 31	7.00 a. m.	45	3.2	120	8.5	11.50	2,181	4	350
" 31	11.49 a. m.	46	3.5	131	....	.08	16	1	45

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
October 31	11.59 a. m.	46	3.3	124	....	.25	48	1	25
" 31	12.14 p. m.	46	3.3	124	3.4	.50	96	1	17
" 31	2.00 p. m.	46	3.2	120	3.8	2.27	467	1	13
" 31	4.00 p. m.	46	3.2	120	4.5	4.27	860	1	12
" 31	6.00 p. m.	46	3.2	120	5.0	6.27	1,245	1	9
" 31	8.00 p. m.	46	3.2	120	5.8	8.27	1,648	1	55
" 31	10.00 p. m.	46	3.2	120	6.4	10.27	2,029	2	210
" 31	12.00 p. m.	46	3.2	120	7.4	12.27	2,411	2	275
November 1	2.00 a. m.	46	3.3	124	7.8	14.27	2,800	2	180
" 1	10.44 a. m.	47	3.4	128	....	.08	16	1	100
" 1	10.54 a. m.	47	3.3	124	....	.25	48	1	55
" 1	11.09 a. m.	47	3.3	124	3.0	.50	93	1	49
" 1	1.00 p. m.	47	3.3	124	3.6	2.35	464	1	29
" 1	3.00 p. m.	47	3.2	120	3.9	4.35	864	1	33
" 1	5.00 p. m.	47	3.3	124	4.2	6.35	1,257	1	17
" 1	7.00 p. m.	47	3.2	120	4.4	8.35	1,640	1	21
" 1	9.00 p. m.	47	3.2	120	4.8	10.35	2,029	1	17
" 1	11.00 p. m.	47	3.4	128	5.0	12.35	2,441	1	15
" 2	1.00 a. m.	47	3.2	120	5.5	14.35	2,825	1	20
" 2	3.00 a. m.	47	3.2	120	5.9	16.35	3,211	1	11
" 2	5.00 a. m.	47	3.2	120	6.2	18.35	3,593	1	19
" 2	7.00 a. m.	47	3.2	120	6.4	20.35	3,977	1	21
" 2	9.00 a. m.	47	3.2	120	6.9	22.35	4,340	1	55
" 2	11.00 a. m.	47	3.2	120	8.5	24.35	4,736	1	75
" 2	1.00 p. m.	47	3.3	124	8.4	26.35	5,168	1	29
" 2	3.00 p. m.	47	3.2	120	9.1	28.35	5,568	2	43
" 2	9.35 p. m.	48	3.2	120	....	.08	16	2	90
" 2	9.45 p. m.	48	3.2	120	....	.25	48	4	190
" 2	10.00 p. m.	48	3.2	120	2.9	.50	96	4	170
" 2	11.00 p. m.	48	3.2	120	3.2	1.50	263	4	120
" 3	1.00 a. m.	48	3.2	120	4.1	3.50	621	5	300
" 3	5.07 a. m.	49	3.2	120	....	.08	16	4	120
" 3	5.17 a. m.	49	3.2	120	....	.25	48	4	120
" 3	5.32 a. m.	49	3.2	120	....	.50	96	4	170
" 3	7.00 a. m.	49	3.3	124	4.2	1.97	411	4	80
" 3	9.00 a. m.	49	3.3	124	4.9	3.97	811	1	60
" 3	11.00 a. m.	49	3.2	120	6.3	5.97	1,194	2	33
" 3	4.08 p. m.	50	3.4	128	....	.08	16	3	36
" 3	4.18 p. m.	50	3.3	124	....	.25	48	4	110
" 3	4.33 p. m.	50	3.3	124	....	.50	96	4	95
" 3	5.03 p. m.	50	3.3	124	3.3	1.00	199	3	85
" 3	5.33 p. m.	50	3.3	124	3.4	1.50	295	3	55
" 3	6.03 p. m.	50	3.2	120	3.5	2.00	387	2	130
" 4	12.05 a. m.	51	3.3	124	....	.08	16	4	140
" 4	12.15 a. m.	51	3.3	124	....	.25	48	5	220
" 4	12.30 a. m.	51	....	....	....	.50	96	5	150
" 4	1.00 a. m.	51	....	....	3.5	1.00	204	5	220
" 4	1.30 a. m.	51	3.2	120	3.7	1.50	300	5	190
" 4	2.00 a. m.	51	....	....	3.8	2.00	392	5	170
" 4	5.05 a. m.	52	3.2	120	3.0	.08	16	5	130
" 4	5.15 a. m.	52	3.2	120	....	.25	48	5	110
" 4	5.30 a. m.	52	3.2	120	....	.50	96	4	230
" 4	6.00 a. m.	52	3.2	120	3.4	1.00	193	4	105
" 4	6.30 a. m.	52	3.2	120	3.5	1.50	283	3	160
" 4	7.00 a. m.	52	3.2	120	3.6	2.00	373	2	65
" 4	2.05 p. m.	53	3.2	120	2.9	.08	16	4	70
" 4	2.15 p. m.	53	3.2	120	....	.25	48	5	170
" 4	2.30 p. m.	53	3.2	120	....	.50	96	4	140
" 4	3.00 p. m.	53	3.2	120	3.1	1.00	181	4	130
" 4	3.30 p. m.	53	3.3	124	3.2	1.50	272	4	90
" 4	4.00 p. m.	53	3.3	124	3.4	2.00	364	4	100
" 4	4.25 p. m.	54	3.2	120	3.4	.08	16	5	100

Results of Bacterial Analyses of Filter No. 20. — Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
November 4	4.35 p. m.	54	3.2	120	3.4	.25	48	5	85
" 4	4.50 p. m.	54	3.2	120	3.4	.50	96	3	110
" 4	6.00 p. m.	54	3.2	120	3.4	1.66	312	2	90
" 4	8.00 p. m.	54	3.3	124	3.9	3.66	706	1	35
" 4	10.00 p. m.	54	3.2	120	4.6	5.66	1,094	2	31
" 4	12 00 p. m.	54	3.3	124	5.0	7.66	1,497	1	16
" 5	12.33 a. m.	55	3.2	120	....	.08	16	3	110
" 5	12.43 a. m.	55	3.2	120	....	.25	48	2	46
" 5	12.58 a. m.	55	3.2	120	2.9	.50	96	1	16
" 5	2.00 a. m.	55	3.2	120	3.2	1.53	291	1	6
" 5	4.00 a. m.	55	3.3	124	3.7	3.53	682	1	0
" 5	6.00 a. m.	55	3.2	120	4.3	5.53	1,055	2	2
" 5	8.00 a. m.	55	....	....	4.0	7.53	1,478	1	2
" 5	10.00 a. m.	55	3.2	120	4.7	9.53	1,822	1	10
" 5	12.00 m.	55	3.2	120	5.2	11.53	2,207	1	11
" 5	2.00 p. m.	55	3.3	124	5.5	13.53	2,598	2	12
" 5	4.00 p. m.	55	3.2	120	5.9	15.53	2,981	2	12
" 5	6.00 p. m.	55	3.4	128	6.7	17.53	3,379	1	5
" 5	8.00 p. m.	55	3.2	120	6.5	19.53	3,771	1	8
" 5	10.00 p. m.	55	3.2	120	7.3	21.53	4,155	2	7
" 5	12.00 p. m	55	3.2	120	7.6	23.53	4,542	1	9
" 6	2.00 a. m.	55	3.3	124	8.0	25.53	4,931	1	12
" 6	4.00 a. m.	55	3.3	124	8.1	27 53	5,318	1	18
" 6	6.00 a. m.	55	3.2	120	8.5	29.53	5,689	1	31
" 6	8.00 a. m.	55	3.3	124	9.4	31.53	6,083	1	15
" 6	10.00 a. m.	55	3 2	120	9.7	33.53	6,447	1	31
" 6	10.52 a. m.	55	3.2	120	9.9	34.40	6,602	2	85
" 6	11.02 a. m.	55	3.2	120	9.9	34.56	6,632	2	75
" 6	11.15 a. m.	55	....	....	10.0	34.80	6,668	1	44
" 6	4.02 p. m.	56	3.2	120	3.0	.08	16	2	29
" 6	4.12 p. m.	56	3.2	120	....	.25	48	2	14
" 6	4.27 p. m.	56	3.2	120	....	.50	96	2	23
" 6	6.00 p. m.	56	3.2	120	3.7	2.05	395	1	12
" 6	8.00 p. m.	56	3.3	124	4.8	4.05	796	1	13
" 6	10.00 p. m.	56	3.2	120	5.5	6.05	1,183	2	115
" 6	12.00 p. m.	56	3.2	120	6.6	8.05	1,565	2	37
" 7	2.00 a. m.	56	3.2	120	7.2	10.05	1,950	2	130
" 7	4 00 a. m.	56	3.2	120	8.1	12.05	2,332	2	170
" 7	6.00 a. m.	56	3 2	120	9.0	14.05	2,618	4	140
" 7	10.05 a. m.	57	3.2	120	....	.08	16	1	37
" 7	10.15 a. m.	57	3 2	120	....	.25	48	1	32
" 7	10 30 a. m.	57	3.2	120	3.6	.50	96	1	7
" 7	12.00 m.	57	....	....	4.2	2.00	385	1	39
" 7	2.00 p. m.	57	3.3	124	4.8	4.00	797	1	34
" 7	4.00 p. m.	57	3.2	120	5.4	6.00	1,188	1	15
" 7	6.00 p. m.	57	3.3	124	6.3	8.00	1,576	1	14
" 7	8.00 p. m.	57	3.2	120	7.0	10.00	1,963	1	15
" 7	10.00 p. m.	57	3.3	124	7.8	12.00	2,358	2	95
" 8	1.40 a. m	58	3.2	120	....	.08	16	2	41
" 8	1.50 a. m.	58	3.2	120	....	.25	48	4	90
" 8	2.05 a. m.	58	3.2	120	3.5	.50	96	3	80
" 8	2.35 a. m.	58	3.2	120	....	1.00	192	2	45
" 8	3.05 a. m.	58	3.2	120	....	1.50	295	1	34
" 8	3.35 a. m.	58	3.2	120	....	2.00	398	1	13
" 8	4.19 a. m.	59	3.2	120	....	.08	16	3	55
" 8	4.29 a. m.	59	3.2	120	....	.25	48	1	22
" 8	4.45 a. m.	59	3.2	120	....	.50	96	1	28
" 8	5.15 a. m.	59	3.2	120	2.8	1.00	192	1	14
" 8	5.45 a. m.	59	3.2	120	3.1	1.50	289	1	26
" 8	6.15 a. m.	59	3.2	120	....	2.00	399	1	36
" 8	7.00 a. m.	60	3.2	120	2.9	.08	16	2	17
" 8	7.15 a. m.	60	3.2	120	....	.25	48	1	24

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
November 8	7.25 a. m.	60	3.2	120	....	.50	96	1	13
" 8	7.55 a. m.	60	3.2	120	3.5	1.00	191	1	30
" 8	8 25 a. m.	60	3 2	120	....	1.50	287	1	6
" 8	8.55 a. m.	60	3.2	120	....	2.00	383	1	30
" 8	9.36 a. m.	61	3.2	120	....	.08	16	2	40
" 8	9.46 a. m.	61	3.3	124	....	.25	48	3	80
" 8	10.01 a. m.	61	3.2	120	3.2	.50	96	3	125
" 8	10.31 a. m.	61	3.2	120	....	1.00	192	3	60
" 8	11.01 a. m.	61	....	....	3.5	1.50	287	4	75
" 8	11.31 a. m.	61	3.2	120	4.1	2.00	384	3	60
" 8	2.35 p. m.	62	3.2	120	2.9	.08	16	3	70
" 8	2.45 p. m.	62	3.2	120	....	.25	48	3	190
" 8	3.00 p. m.	62	3.2	120	3.4	.50	96	4	140
" 8	3.30 p. m.	62	3.2	120	3.5	1.00	192	3	275
" 8	4.00 p. m.	62	3.2	120	3.7	1.50	287	3	160
" 8	4.30 p. m.	62	3.2	120	3.9	2.00	384	3	130
" 8	5.35 p. m.	63	3.2	120	3.0	.08	16	3	180
" 8	5.45 p. m.	63	3.2	120	....	.25	48	3	220
" 8	6.00 p. m.	63	3.2	120	3.1	.50	96	2	180
" 8	6.30 p. m.	63	3.2	120	....	1.00	192	2	180
" 8	7.00 p. m.	63	3.3	124	3.8	1.50	289	2	150
" 8	7.30 p. m.	63	3.2	120	3.9	2.00	392	2	226
" 9	2 40 a. m.	64	3.2	120	3.6	.08	16	4	300
" 9	2.50 a. m.	64	3.2	120	....	.25	48	5	800
" 9	3.05 a. m.	64	3 2	120	3.0	.50	96	5	2,200
" 9	4.35 a. m.	64	3.2	120	....	1.02	186	5	1,100
" 9	5.05 a. m.	64	3.2	120	3.3	1.52	276	5	950
" 9	5.35 a. m.	64	3.2	120	3.4	2.02	372	5	1,600
" 9	6.35 a. m.	64	3.2	120	3.6	3.02	563	5	1,100
" 9	7.35 a. m.	64	3.2	120	3.7	4.02	760	5	1,000
" 9	8.35 a. m.	64	3.3	124	3.7	5.02	963	4	1,100
" 9	9.35 a. m.	64	3.2	120	3.9	6.02	1,144	4	950
" 9	10.30 a. m.	64	3.2	120	4.1	7.02	1,307	4	900
" 9	10 55 a. m.	65	3.2	120	3.4	.08	16	4	1,500
" 9	11.05 a. m.	65	3.2	120	3.4	.25	48	4	1,200
" 9	11.20 a. m.	65	3.2	120	....	.50	96	4	950
" 9	11.50 a. m.	65	3.2	120	3.5	1.00	198	4	1,100
" 9	12.20 p. m.	65	3.2	120	3.6	1.50	284	4	1,200
" 9	12.50 p. m.	65	3.2	120	3.8	2.00	395	4	800
" 9	1.50 p. m.	65	3.2	120	4.1	3.00	592	3	850
" 9	2.50 p. m.	65	3.2	120	4.4	4.00	782	3	650
" 9	3 50 p. m.	65	3.2	120	4.7	5 00	979	2	950
" 9	4.50 p. m.	65	3 2	120	5.1	6 00	1,174	2	120
" 9	5 50 p. m.	65	3.2	120	....	7.00	1,371	2	375
" 9	6.15 p. m.	66	3.2	120	....	.08	16	4	600
" 9	6.25 p. m.	66	3.2	120	....	.25	48	4	500
" 9	6.40 p. m.	66	3.2	120	3.4	.50	96	2	400
" 9	7.10 p. m.	66	3.2	120	3.4	1 00	192	2	150
" 9	7.40 p. m.	66	3.2	120	3.7	1.50	288	3	375
" 9	8.10 p. m.	66	3.2	120	3.8	2.00	386	3	300
" 9	9 10 p. m.	66	3.2	120	3.9	3.00	585	2	300
" 9	10.10 p. m.	66	3.4	128	4.6	4.00	784	2	160
" 9	11.10 p. m.	66	3.3	124	4.9	5 00	982	2	250
" 10	12.10 a. m.	66	3.3	124	4.7	6.00	1,178	1	170
" 10	1.10 a. m.	66	3 2	120	4.8	7.00	1,368	1	100
" 10	1.42 a. m.	67	3.2	120	3.0	.08	16	3	450
" 10	1.52 a. m.	67	3.2	120	3.1	.25	48	2	300
" 10	2.07 a. m.	67	3.2	120	3.1	.50	96	1	230
" 10	3.00 a. m.	67	3.2	120	3.4	1.38	250	1	120
" 10	5.00 a. m.	67	3.2	120	4.2	3.38	627	1	140
" 10	7.00 a. m.	67	3.2	120	5.1	5.38	1,000	1	120
" 10	9.00 a. m.	67	3.2	120	5.3	7.38	1,393	1	190

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
November 10	11.00 a. m.	67	3.2	120	6.0	9.38	1,767	1	80
" 10	1.00 p. m.	67	3.2	120	6.5	11.38	2,151	1	55
" 10	3.00 p. m.	67	3.2	120	7.2	13.38	2,523	1	100
" 10	5.00 p. m.	67	3.3	124	8.1	15.38	2,917	1	140
" 10	7.00 p. m.	67	3.2	120	8.4	17.38	3,306	2	100
" 10	9.00 p. m.	67	3.2	120	9.1	19.38	3,687	2	425
" 10	11.00 p. m.	67	3.2	120	9.4	21.38	4,063	2	275
" 11	1.00 a. m.	67	3.2	120	9.7	23.38	4,441	1	300
" 11	2.00 a. m.	67	3.2	120	9.9	24.38	4,614	1	300
" 11	6.55 a. m.	68	3.2	120	3.1	.08	16	4	650
" 11	7.05 a. m.	68	3.2	120	....	.25	48	4	600
" 11	10.05 a. m.	69	3.2	120	3.0	.08	16	2	65
" 11	10.15 a. m.	69	3.2	120	....	.25	48	3	200
" 11	10.30 a. m.	69	3.2	120	3.2	.50	96	2	170
" 11	11.00 a. m.	69	3.2	120	3.5	1.00	182	1	150
" 11	11.30 a. m.	69	3.2	120	3.8	1.50	278	1	75
" 11	12.00 m.	69	3.2	120	4.1	2.00	379	1	110
" 11	5.09 p. m.	70	3.2	120	....	.08	16	3	250
" 11	5.19 p. m.	70	3.2	120	2.9	.25	48	2	210
" 11	5.30 p. m.	70	3.2	120	2.9	.50	96	1	46
" 11	6.00 p. m.	70	3.2	120	2.9	1.00	177	1	150
" 11	6.30 p. m.	70	3.2	120	3.2	1.50	279	1	120
" 11	7.00 p. m.	70	3.2	120	3.4	2.00	371	1	120
" 11	8.00 p. m.	70	3.2	120	3.6	3.00	562	1	275
" 11	9.00 p. m.	70	3.4	128	4.3	4.00	774	1	150
" 11	10.00 p. m.	70	3.4	128	4.2	5.00	977	1	110
" 11	11.00 p. m.	70	3.3	124	4.4	6.00	1,173	1	85
" 11	12.00 p. m.	70	3.2	120	4.6	6.93	1,369	1	31
" 12	12.32 a. m.	71	3.2	120	3.1	.08	16	3	180
" 12	12.42 a. m.	71	3.2	120	3.2	.25	48	2	100
" 12	1.00 a. m.	71	3.2	120	3.3	.50	103	1	80
" 12	1.30 a. m.	71	3.2	120	3.3	1.05	201	1	44
" 12	2.00 a. m.	71	3.2	120	3.3	1.55	297	1	55
" 12	2.30 a. m.	71	3.2	120	3.3	2.05	393	1	65
" 12	6.54 a. m.	72	3.2	120	2.9	.08	16	1	150
" 12	7.05 a. m.	72	3.2	120	2.9	.25	48	4	500
" 12	7.20 a. m.	72	3.2	120	2.9	.50	96	4	275
" 12	8.05 a. m.	73	3.2	120	3.0	.08	16	3	210
" 12	8.15 a. m.	73	3.2	120	3.1	.25	48	1	100
" 12	8.30 a. m.	73	3.2	120	3.3	.50	96	1	110
" 12	10.00 a. m.	73	3.2	120	4.0	2.00	379	1	65
" 12	12.00 m.	73	3.2	120	5.0	4.00	757	1	140
" 12	2.00 p. m.	73	3.2	120	5.9	6.00	1,143	1	70
" 12	4.00 p. m.	73	3.2	120	6.7	8.00	1,514	2	375
" 12	6.00 p. m.	73	3.2	120	8.0	10.00	1,881	1	250
" 12	8.05 p. m.	74	3.3	120	....	.08	16	2	110
" 12	8.15 p. m.	74	3.3	120	....	.25	48	1	65
" 12	8.30 p. m.	74	3.3	120	....	.50	96	1	90
" 12	9.00 p. m.	74	3.2	120	3.5	1.00	192	1	110
" 12	9.30 p. m.	74	3.2	120	3.7	1.50	288	1	150
" 12	10.00 p. m.	74	3.2	120	3.9	2.00	384	1	80
" 12	11.10 p. m.	75	3.2	120	....	.08	16	2	210
" 12	11.20 p. m.	75	3.2	120	2.9	.25	48	1	120
" 12	11.35 p. m.	75	3.2	120	2.9	.50	96	1	160
" 13	1.00 a. m.	75	3.2	120	3.4	1.92	338	1	180
" 13	3.00 a. m.	75	3.2	120	4.8	3.92	717	2	800
" 13	5.00 a. m.	75	3.2	120	6.3	5.92	1,099	2	1,400
" 13	7.00 a. m.	75	3.2	120	7.2	7.92	1,481	3	2,500
" 13	7.45 a. m.	76	3.2	120	2.9	.08	16	1	400
" 13	7.55 a. m.	76	3.2	120	2.9	.25	48	1	325
" 13	8.10 a. m.	76	3.2	120	8.0	.50	96	1	500
" 13	10.00 a. m.	76	3.2	120	3.9	2.33	446	1	80

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
November 13	12.00 m.	76	3.3	124	5.9	4.33	846	3	2,100
" 13	7.20 p. m.	77	3.2	120	....	.10	16	4	1,500
" 13	7.30 p. m.	77	3.2	120	....	.25	48	4	1,300
" 13	7.55 p. m.	78	3.2	120	3.4	.17	16	3	900
" 13	8.00 p. m.	78	3.2	120	3.4	.33	48	1	650
" 13	8.15 p. m.	78	3.2	120	....	.58	96	1	800
" 13	10.00 p. m.	78	....	....	4.2	2.25	452	1	200
" 13	12.00 p. m.	78	3.0	112	5.7	4.45	815	1	325
" 14	2.00 a. m.	78	3.3	124	7.5	6.45	1,214	4	1,100
" 14	2.45 a. m.	79	3.3	124	3.5	.08	16	3	1,200
" 14	2.55 a. m.	79	3.3	124	3.5	.25	48	1	600
" 14	3.10 a. m.	79	3.3	124	3.6	.50	96	2	1,100
" 14	5.00 a. m.	79	3.2	120	4.9	2.33	450	1	1,300
" 14	7.00 a. m.	79	3.2	120	6.5	4.33	844	4	2,900
" 14	8.33 a. m.	80	3.2	120	7.1	.08	16	4	1,100
" 14	8.43 a. m.	80	....	....	7.3	.25	48	3	1,200
" 14	8.58 a. m.	80	3.2	120	3.0	.50	96	1	350
" 14	9.28 a. m.	80	3.3	124	3.6	1.00	192	1	400
" 14	11.28 a. m.	80	3.2	120	4.8	3.00	576	1	600
" 14	12.28 p. m.	80	3.2	120	5.5	4.00	727	3	1,300
" 14	2.35 p. m.	81	3.2	120	....	.08	16	2	3,800
" 14	2.45 p. m.	81	3.2	120	....	.25	48	1	250
" 14	3.00 p. m.	81	3.2	120	3.2	50	96	1	210
" 14	3.30 p. m.	81	3.2	120	3.6	1.00	196	1	130
" 14	4.30 p. m.	81	....	....	4.3	2.00	382	1	100
" 14	5.30 p. m.	81	3.2	120	4.3	3.00	579	1	110
" 14	6.30 p. m.	81	3.3	124	4.5	4.00	778	1	35
" 14	7.30 p. m.	81	....	....	5.0	5.00	973	1	13
" 14	8.30 p. m.	81	3.2	120	5.5	6.00	1,160	1	42
" 14	9.30 p. m.	81	3.2	120	5.8	7.00	1,344	1	43
" 14	10.30 p. m.	81	3.2	120	6.3	8.00	1,528	1	10
" 14	11.30 p. m.	81	3.2	120	7.2	9.00	1,716	1	36
" 15	12.30 a. m.	81	3.2	120	7.4	10.00	1,910	1	55
" 15	1.30 a. m.	81	3.2	120	7.8	11.00	2,100	1	160
" 15	2.30 a. m.	81	3.2	120	8.2	12.00	2,287	2	300
" 15	3.30 a. m.	81	3.2	120	10 0	13.00	2,479	2	800
" 15	9.22 a. m.	82	3.2	120	2.8	.08	16	2	400
" 15	9.32 a. m.	82	3.2	120	....	.25	48	4	1,100
" 15	9.42 a. m.	82	3.2	120	3.2	.42	96	4	950
" 15	10.11 a. m.	83	3.2	120	2.8	.08	16	2	325
" 15	10.21 a. m.	83	3.2	120	....	.25	48	1	275
" 15	10.36 a. m.	83	3.2	120	3.3	.50	96	1	300
" 15	12.00 m.	83	3.2	120	4.0	1.90	367	1	130
" 15	2.00 p. m.	83	....	....	6.3	3.90	725	1	325
" 15	8.50 p. m.	84	3.2	120	....	.08	16	4	400
" 15	9.00 p. m.	84	3.2	120	3.2	.25	48	1	325
" 15	9.30 p. m.	84	3.2	120	....	.75	96	1	190
" 15	10.00 p. m.	84	3.2	120	3.5	1.27	243	1	150
" 15	11.00 p. m.	84	3.2	120	4.1	2.27	437	1	85
" 15	12.00 p. m.	84	3.1	116	4.6	3.27	622	1	110
" 16	1.00 a. m.	84	3.4	128	5.1	4.27	820	1	110
" 16	2.00 a. m.	84	3.4	128	5.6	5.27	1,024	1	80
" 16	3.00 a. m.	84	3.1	116	6.0	6.27	1,208	1	95
" 16	4.00 a. m.	84	3.2	120	6.5	7.27	1,402	1	75
" 16	5.00 a. m.	84	3.0	112	7.5	8.27	1,588	1	100
" 16	6.00 a. m.	84	3.2	120	7.7	9.27	1,780	1	90
" 16	7.00 a. m.	84	3.2	120	8.3	10.27	1,974	1	49
" 16	2.10 p. m.	85	3.2	120	3.0	.08	16	1	230
" 16	2.20 p. m.	85	3.2	120	....	.25	48	1	210
" 16	2.35 p. m.	85	3.2	120	3.2	.50	96	1	110
" 16	4.00 p. m.	85	3.2	120	3.6	1.92	373	1	120
" 16	5.00 p. m.	85	3.3	124	3.7	2.92	576	1	110

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
November 16	6.00 p. m.	85	3.3	124	3.8	3.92	772	1	85
" 16	8.00 p. m.	85	3.3	124	3.9	5.92	1,166	1	70
" 16	10.00 p. m.	85	3.2	120	4.2	7.92	1,535	1	110
" 16	12.00 p. m.	85	3.0	112	4.5	9.92	1,899	1	140
" 17	2.00 a. m.	85	3.4	128	5.3	11.92	2,302	1	110
" 17	4.00 a. m.	85	3.0	112	4.5	13.92	2,686	1	75
" 17	6.00 a. m.	85	3.3	124	5.8	15.92	3,034	1	90
" 17	8.00 a. m.	85	....	....	6.0	17.92	3,434	1	130
" 17	10.00 a. m.	85	3.3	124	6.3	19.92	3,826	1	170
" 17	12.00 m.	85	3.2	120	6.6	21.92	4,210	1	120
" 17	2.00 p. m.	85	3.2	120	7.0	23.92	4,591	1	150
" 17	4.00 p. m.	85	....	....	7.2	25.92	4,968	1	190
" 17	6.00 p. m.	85	3.2	120	7.7	27.92	5,350	1	275
" 17	8.00 p. m.	85	3.2	120	7.9	29.92	5,734	1	300
" 17	10.00 p. m.	85	3.2	120	8.2	31.92	6,110	2	125
" 17	12.00 p. m.	85	3.2	120	9.2	33.92	6,493	2	220
" 18	6.15 a. m.	86	3.2	120	....	.08	16	2	340
" 18	6.25 a. m.	86	3.2	120	....	.25	48	1	200
" 18	6.40 a. m.	86	3.2	120	3.6	.50	96	1	225
" 18	8.00 a. m.	86	3.2	120	4.4	1.83	354	1	150
" 18	9.43 a. m.	86	3.2	120	5.5	3.57	691	1	300
" 18	4.30 p. m.	87	3.2	120	....	.08	16	2	150
" 18	4.40 p. m.	87	3.2	120	2.8	.25	48	2	110
" 18	4.55 p. m.	87	3.2	120	2.8	.50	96	1	70
" 18	6.00 p. m.	87	3.2	120	3.4	1.60	302	2	50
" 18	8.00 p. m.	87	3.2	120	4.1	3.60	686	1	55
" 18	10.00 p. m.	87	3.2	120	5.0	5.60	1,070	1	92
" 18	12.00 p. m.	87	3.2	120	5.5	7.60	1,453	2	19
" 19	2.00 a. m.	87	3.3	124	6.2	9.60	1,848	1	20
" 19	4.00 a. m.	87	3.2	120	6.7	11.60	2,234	1	21
" 19	6.00 a. m.	87	3.4	128	7.5	13.60	2,638	1	28
" 19	8.00 a. m.	87	3.3	124	7.9	15.60	3,029	2	275
" 19	9.55 a. m.	87	3.2	120	....	17.53	3,389	2	425
" 19	4.35 p. m.	88	3.2	120	2.9	.08	16	1	60
" 19	4.45 p. m.	88	3.2	120	2.9	.25	48	1	43
" 19	5.00 p. m.	88	3.2	120	3.1	.50	100	1	17
" 19	7.00 p. m.	88	3.2	120	3.3	2.50	483	1	10
" 19	9.00 p. m.	88	3.2	120	3.5	4.50	867	1	19
" 19	11.00 p. m.	88	3.2	120	4.0	6.50	1,251	1	4
" 20	1.00 a. m.	88	3.4	128	4.3	8.50	1,653	1	18
" 20	3.00 a. m.	88	3.4	128	4.7	10.50	2,055	1	35
" 20	5.00 a. m.	88	3.2	120	5.2	12.50	2,438	1	19
" 20	7.00 a. m.	88	3.3	124	5.6	14.50	2,833	1	12
" 20	9.00 a. m.	88	3.2	120	6.0	16.50	3,215	1	15
" 20	11.00 a. m.	88	3.4	128	6.3	18.50	3,623	1	18
" 20	1.00 p. m.	88	3.2	120	6.7	20.50	4,016	2	90
" 20	3.00 p. m.	88	3.2	120	6.9	22.50	4,412	2	85
" 20	5.00 p. m.	88	3.3	124	7.0	24.50	4,769	2	375
" 20	7.00 p. m.	88	3.2	120	7.0	26.50	5,144	2	230
" 20	9.00 p. m.	88	3.2	120	8.0	28.50	5,509	2	250
" 20	11.00 p. m.	88	3.2	120	8.5	30.50	5,890	2	275
" 21	1.00 a. m.	88	3.4	128	9.0	32.50	6,285	2	230
" 21	1.50 a. m.	89	3.4	128	3.2	.08	16	2	230
" 21	2.00 a. m.	89	3.4	128	3.4	.25	48	1	70
" 21	2.15 a. m.	89	3.4	128	3.4	.50	96	1	50
" 21	4.00 a. m.	89	3.2	120	3.6	2.25	423	2	19
" 21	6.00 a. m.	89	3.4	128	4.3	4.25	811	1	30
" 21	8.00 a. m.	89	3.4	128	4.6	6.25	1,244	1	34
" 21	10.15 a. m.	90	4.1	154	....	.12	29	1	34
" 21	10.30 a. m.	90	4.1	154	....	.38	92	1	22
" 21	11.00 a. m.	90	4.0	150	4.3	.87	242	1	26
" 21	11.30 a. m.	90	4.1	154	4.4	1.30	358	1	8

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
November 21	12.00 m.	90	4.1	154	4.5	1.80	474	1	34
" 21	1.00 p. m.	90	4.0	150	4.9	2.80	707	1	12
" 21	2.00 p. m.	90	3.9	146	5.2	3.80	949	2	16
" 21	3.00 p. m.	90	4.3	161	5.8	4.80	1,193	1	5
" 21	4.00 p. m.	90	....	....	6.5	5.80	1,452	1	4
" 21	7.10 p. m.	91	3.2	120	2.9	.08	16	1	60
" 21	7.20 p. m.	91	3.2	120	2.9	.25	48	1	35
" 21	7.35 p. m.	91	3.2	120	3.2	.50	96	1	19
" 21	9.00 p. m.	91	3.2	120	3.5	1.92	356	1	20
" 21	11.00 p. m	91	3.2	120	4.6	3.92	732	1	11
" 22	1.00 a. m.	91	3.4	128	5.7	5.92	1,149	2	21
" 22	3.00 a. m.	91	3.3	124	6.2	7.92	1,554	1	49
" 22	5.00 a. m.	91	3.3	124	7.1	9.92	1,947	1	11
" 22	7.00 a. m.	91	3.2	120	7 6	11.92	2,332	1	55
" 22	9.00 a. m.	91	3.3	124	8.8	13.92	2,717	1	85
" 22	11.00 a m	91	3.2	120	9.6	15.92	3,095	1	110
" 22	12.30 p. m.	91	3.3	124	2.9	17.42	3,397	2	85
" 22	12.55 p. m.	92	3.2	120	2.9	.08	16	1	65
" 22	1.05 p. m.	92	3.3	124	3.1	.25	48	1	47
" 22	1.25 p. m.	92	3.3	124	3.2	.50	96	1	60
" 22	3.00 p. m.	92	....	....	3.4	2.17	419	1	24
" 22	5.00 p. m.	92	3.2	120	4.5	4.17	802	1	26
" 22	7.00 p. m.	92	3.2	120	4.6	6.17	1,187	1	16
" 22	9.00 p. m.	92	8.3	124	4.7	8.17	1,577	2	5
" 22	11.00 p. m.	92	3.2	120	4.9	10.17	1,959	1	4
" 23	1.00 a. m.	92	3.4	128	5.3	12.17	2,339	1	11
" 23	3.00 a. m.	92	3.3	124	5.5	14.17	2,737	1	20
" 23	5.00 a. m.	92	3.2	120	5.8	16.17	3,131	2	60
" 23	7.00 a. m.	92	3.4	128	6.6	18.17	3,526	1	12
" 23	9.30 a. m.	92	....	....	6.8	20.67	3,958	1	75
" 23	11.30 a. m.	92	....	....	7.4	22.67	4,308	1	110
" 23	1.30 p. m.	92	3.3	....	7.8	24.67	4,711	2	140
" 23	2.56 p. m.	93	4.4	165	....	.08	22	2	70
" 23	3.06 p. m.	93	4.4	165	5.8	.25	66	2	43
" 23	3.21 p. m.	93	4.6	172	5.9	.50	132	1	23
" 23	5.00 p. m.	93	4.6	172	6.1	2.15	638	1	7
" 23	7.00 p. m.	93	4.6	172	6.1	4.15	1,172	1	2
" 23	9.00 p. m.	93	4.4	165	6.4	6.15	1,693	1	4
" 25	2.45 a. m.	94	4.4	165	....	.08	22	2	23
" 25	2.55 a. m.	94	4.4	165	....	.25	66	1	27
" 25	3.10 a m.	94	4.4	165	....	.50	110	1	18
" 25	5.00 a. m.	94	....	....	6.0	2 33	580	1	11
" 25	7.00 a. m.	94	4.8	180	7.2	4.33	1,104	1	6
" 25	8.55 a. m.	95	3.4	128	3.2	.08	16	1	20
" 25	9.05 a. m.	95	3.3	124	3.4	.25	48	1	14
" 25	9.20 a. m.	95	3.3	124	3.5	.50	96	1	9
" 25	11.00 a. m.	95	3 2	120	3.6	2.17	319	1	8
" 25	1.00 p. m.	95	3.2	120	4.1	4.17	793	1	11
" 25	3.00 p. m.	95	3.3	124	5.1	6.17	1,197	1	16
" 25	5.00 p. m.	95	3.3	124	5.5	8.17	1,608	1	15
" 25	7.00 p. m.	95	3.2	120	5.2	10.17	2,001	1	14
" 25	9.00 p. m.	95	3.2	120	5.5	12.17	2,356	1	22
" 25	11.00 p. m.	95	3.3	124	6.1	14.17	2,751	1	16
" 26	1.00 a. m.	95	....	....	6.4	16.17	3,126	1	43
" 26	3.00 a. m.	95	3.3	124	8.0	18.17	3,523	2	65
" 26	4.20 a. m.	96	4.0	....	....	.08	20	3	350
" 26	4.30 a. m.	96	4.0	....	....	.25	60	4	230
" 26	4.45 a. m.	96	4.4	165	5.2	.50	120	4	325
" 26	5.55 a. m.	97	3.2	120	3.2	.08	16	4	350
" 26	6.05 a. m.	97	3.2	120	3.2	.25	48	4	375
" 26	6.20 a. m.	97	3.2	120	3.4	.50	96	4	350
" 26	9.20 a. m.	98	3.2	120	....	.08	16	4	400

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
November 26	9.30 a. m.	98	3.2	120	....	.25	48	4	375
" 26	2.10 p. m.	99	4.4	165	...	.08	22	2	150
" 26	2.20 p. m.	99	4.4	165	....	.25	66	2	14
" 26	2.35 p. m.	99	4.4	165	5.6	.50	133	1	10
" 26	4.00 p. m.	99	4.3	161	5.7	1.92	497	1	7
" 26	6.00 p. m.	99	4.3	161	6.3	3.92	1,025	1	4
" 26	8.00 p. m.	99	4.3	161	7.0	5.92	1,555	1	9
" 26	10.00 p. m.	99	4.3	161	7.5	7.92	2,088	1	65
" 26	11.30 p. m.	99	4.4	165	8.2	9.42	2,488	2	95
" 26	11.58 p. m.	100	3.2	120	3.3	.08	16	1	70
" 27	12.08 a. m.	100	3.2	120	3.3	.25	48	1	16
" 27	12.23 a. m.	100	3.2	120	3.4	.50	96	1	47
" 27	2.00 a. m.	100	3.2	120	3.9	2.12	396	1	9
" 27	4.00 a. m.	100	3.2	120	5.8	4.12	804	1	14
" 27	6.00 a. m.	100	3.4	128	6.1	6.12	1,206	1	17
" 27	8.00 a. m.	100	3.4	128	6.5	8.12	1,668	1	16
" 27	10.00 a. m.	100	3.2	120	6.6	10.12	2,072	1	43
" 27	12.00 m.	100	3.4	128	6.6	12.12	2,486	1	60
" 27	2.00 p. m.	100	3.2	120	6.4	14.12	2,880	1	130
" 27	4.10 p. m.	101	4.4	165	....	.08	22	1	90
" 27	4.20 p. m.	101	4.4	165	....	.25	67	1	19
" 27	4.35 p. m.	101	4.4	165	5.2	.50	132	1	9
" 27	6.00 p. m.	101	4.4	165	5.8	1.92	501	1	14
" 27	8.00 p. m.	101	4.4	165	6.5	3.92	1,037	1	18
" 27	10.00 p. m.	101	4.4	165	6.6	5.92	1,572	2	130
" 27	11.00 p. m.	101	4.4	165	6.7	6.92	1,829	2	180
" 28	5.10 a. m.	102	3.2	....	3.2	.08	16	1	35
" 28	5.20 a. m.	102	3.2	....	3.2	.25	48	2	19
" 28	5.35 a. m.	102	3.2	120	....	.50	96	1	11
" 28	7.00 a. m.	102	3.2	120	3.5	1.92	354	1	21
" 28	9.00 a. m.	102	3.4	128	4.5	3.92	721	1	17
" 28	11.00 a. m.	102	3.3	124	4.5	5.92	1,114	1	16
" 28	1.00 p. m.	102	3.2	120	4.9	7.92	1,502	1	25
" 28	3.00 p. m.	102	3.2	120	5.1	9.92	1,846	1	20
" 28	5.00 p. m.	102	3.2	120	5.4	11 92	2,198	1	95
" 28	7.00 p. m.	102	3.2	120	5.9	13.92	2,584	1	110
" 28	9.00 p. m.	102	3.3	124	6.1	15.92	2,968	2	250
" 28	11.00 p. m.	102	3.3	124	6.6	17.92	3,354	1	140
" 29	1.00 a. m.	102	....	....	7.2	19.92	3,740	2	250
" 29	8.10 a. m.	103	3.2	120	....	.08	16	1	55
" 29	8.20 a. m.	103	3.2	120	....	.25	48	2	170
" 29	8.35 a. m.	103	3.3	124	....	.50	96	3	400
" 29	9.05 a. m.	103	3.3	124	3.9	1.00	185	4	400
" 29	3.25 p. m.	104	3.2	120	....	.08	16	3	140
" 29	3.35 p. m.	104	3.2	120	....	.25	48	4	120
" 29	3.50 p. m.	104	3.2	120	....	.50	96	2	130
" 29	10.35 p. m.	105	3.2	120	....	.08	16	3	160
" 29	10.45 p. m.	105	3.2	120	....	.25	48	4	275
" 29	11.00 p. m.	105	3.2	120	3.3	.50	96	4	475
" 30	5.38 a. m.	106	3.2	120	....	.08	16	4	140
" 30	5.48 a. m.	106	3.2	120	....	.25	48	3	100
" 30	6.03 a. m.	106	3.2	120	3.2	.50	96	2	75
" 30	8.00 a. m.	106	3.2	120	4.3	2.45	461	1	48
" 30	10.00 a. m.	106	3.3	124	4.4	4.45	835	1	27
" 30	12.00 m	106	3.2	120	4.8	6.45	1,119	1	22
" 30	2.00 p. m.	106	3.3	124	5.4	8.45	1,606	1	22
" 30	4.00 p. m.	106	3.3	124	5.8	10.45	1,998	1	13
" 30	6.00 p. m.	106	3.2	120	6.0	12.45	2,387	1	10
" 30	8.00 p. m.	106	3.2	120	6.6	14.45	2,771	1	13
" 30	10.00 p. m.	106	3.2	120	6.6	16.45	3,155	1	17
" 30	12.00 p. m.	106	3.2	120	7.7	18.45	3,539	1	100

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
December 1.....	2.00 a. m.	106	3.2	120	8.1	20.45	3,923	1	160
" 1.....	4.00 a. m.	106	3.2	120	8.4	22.45	4,311	1	200
" 1.....	10.40 a. m.	107	3.2	120	3.5	.08	16	2	65
" 1.....	10.50 a. m.	107	3.2	120	3.5	.25	48	1	17
" 1.....	11.05 a. m.	107	3.2	120	3.5	.50	96	1	4
" 1.....	12 00 m.	107	3.2	120	3.5	1.42	270	1	9
" 1.....	2.00 p. m.	107	3.2	120	4.0	3.42	654	1	11
" 1.....	4.00 p. m.	107	3.2	120	4.1	5.42	1,038	1	18
" 1.....	6.00 p. m.	107	3.2	120	4.7	7.42	1,426	1	6
" 1.....	8.00 p. m.	107	3.2	120	5.0	9.42	1,808	1	7
" 1.....	10.00 p. m.	107	3.2	120	5.0	11.42	2,192	1	6
" 1.....	12.00 p. m.	107	3.2	120	6.2	13.42	2,582	1	18
" 2.....	2.00 a. m.	107	3.2	120	6.4	15.42	2,970	2	13
" 2.....	4.00 a. m.	107	3.3	124	6.7	17.42	3,361	2	130
" 2.....	6.02 a. m.	108	4.4	165	4.5	.08	22	1	80
" 2.....	6.12 a. m.	108	4.4	165	4.6	.25	66	1	33
" 2.....	6.27 a. m.	108	4.4	165	4.7	.50	110	1	11
" 2.....	8.00 a. m.	108	4.3	161	5.6	2.05	519	1	10
" 2.....	10.00 a. m.	108	4.4	165	6.2	4.05	1,054	1	12
" 2.....	12.00 m.	108	4.4	165	6.7	6.05	1,587	2	95
" 2.....	2.00 p. m.	108	4.4	165	7.3	8.05	2,121	2	400
" 2.....	6.55 p. m.	109	3.2	120	2.9	.08	16	2	65
" 2.....	7.05 p. m.	109	3.2	120	3.0	.25	48	1	26
" 2.....	7.20 p. m.	109	3.2	120	3.1	.50	96	1	25
" 2.....	9.00 p. m.	109	3.2	120	4.1	2.17	417	1	13
" 2.....	11.00 p. m.	109	3.2	120	5.0	4.17	795	1	12
" 3.....	1.00 a. m.	109	3.2	120	5.7	6.17	1,184	1	16
" 3.....	3.00 a. m.	109	3.2	120	6.3	8.17	1,572	1	75
" 3.....	5.00 a. m.	109	3.2	120	7.1	10.17	1,955	2	325
" 3.....	5.30 a. m.	110	4.4	165	5.4	.08	22	1	90
" 3.....	5.40 a. m.	110	4.4	165	5.4	.25	66	1	25
" 3.....	5.55 a. m.	110	4.4	165	5.4	.50	110	1	7
" 3.....	7.00 a. m.	110	4.3	161	6.1	1.58	420	1	5
" 3.....	9.00 a. m.	110	4.4	165	6.9	3.58	956	1	60
" 3.....	11.00 a. m.	110	4.4	165	8.0	5.58	1,489	2	190
" 3.....	11.45 a. m.	111	3.2	120	3.1	.08	16	2	25
" 3.....	11.55 a. m.	111	3.2	120	3.3	.25	48	1	22
" 3.....	12.10 p. m.	111	3.2	120	3.3	.50	96	1	11
" 3.....	1.00 p. m.	111	3.2	120	4.0	1 33	257	1	7
" 3.....	3.00 p. m.	111	3.2	120	5.0	3.33	641	2	130
" 3.....	5.00 p. m.	111	3.2	120	6.6	5.33	1,025	1	8
" 3.....	7.00 p. m.	111	3.2	120	7.8	7.33	1,408	1	46
" 3.....	9.00 p. m.	111	3.2	120	8.8	9.33	1,792	1	275
" 3	9.50 p. m.	112	4.4	165	4.0	.03	9	1	150
" 3.....	10.00 p. m.	112	4.4	165	4.4	.20	53	1	110
" 3	10.15 p. m.	112	4.4	165	5.6	.45	119	1	22
" 3.	12.00 p. m.	112	4.4	165	7.2	2.20	641	1	17
" 4.....	2.00 a. m.	112	4.3	161	8.4	4.20	1,167	2	55
" 4.....	4.00 a. m.	112	4.1	154	9.6	6.20	1,557	1	120
" 4.....	4.55 a. m.	113	3.2	120	3.6	.08	16	1	75
" 4.....	5.05 a. m.	113	3.2	120	3.6	.25	48	1	55
" 4.....	5.20 a. m.	113	3.2	120	3.7	.50	96	1	45
" 4.....	7.00 a. m.	113	3.2	120	4.2	2.17	422	1	50
" 4.....	9.00 a. m.	113	3.2	120	4.8	4.17	812	1	44
" 4.....	11.00 a. m.	113	3.2	120	5.4	6.17	1,196	1	140
" 4.....	1.00 p. m.	113	3.2	120	6.1	8.17	1,580	2	100
" 4.....	3.00 p. m.	113	3.2	120	6.7	10.17	1,964	1	160
" 4	5.00 p. m.	113	3.2	120	7.8	12 17	2,332	1	130
" 4.....	6.15 p. m.	114	3.2	120	.....	.08	16	1	.....
" 4.....	6.25 p. m.	114	3.2	120	.....	.25	48	1	85
" 4.....	6.40 p. m.	114	3.2	120	3.8	.50	96	2	55
" 4.....	8.00 p. m.	114	3.2	120	4.5	1.83	345	1	.....

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet	Hours	Cubic Feet.		
December 4	10.00 p. m.	114	3.2	120	5.3	3.83	736	1	.....
" 4	12.00 p. m.	114	3.2	120	6.8	5.83	1,118	2	.....
" 6	4.50 p. m.	115	3.2	120	5.6	.08	16	3	2,200
" 6	5.00 p. m.	115	3.2	120	5.6	.25	48	1	6,700
" 6	5.15 p. m.	115	3.2	120	5.8	.50	96	1	4,000
" 6	7.00 p. m.	115	3.2	120	6.6	2.25	445	1	3,800
" 6	9.00 p. m.	115	3.2	120	7.6	4.25	839	1	900
" 6	11.00 p. m.	115	3.2	120	8.5	6.25	1,209	1	575
" 7	1.00 a. m.	115	3.2	120	9.6	8.25	1,580	1	650
" 7	2.00 a. m.	115	3.2	120	10.0	9.25	1,759	1	475
" 7	8.40 a. m.	116	3.2	120	5.7	.10	16	1	300
" 7	8.50 a. m.	116	3.2	120	5.8	.27	48	1	750
" 7	9.05 a. m.	116	3.2	120	5.9	.52	96	1	700
" 7	10.00 a. m.	116	3.2	120	6.6	1.43	272	1	700
" 7	12.00 m.	116	3.2	120	7.5	3.43	658	1	550
" 7	2.00 p. m.	116	3.2	120	8.2	5.43	1,041	1	450
" 7	4.00 p. m.	116	3.2	120	9.8	7.43	1,420	1	350
" 7	4.28 p. m.	116	3.2	120	9.4	8.90	1,509	1	650
" 7	4.43 p. m.	116	3.2	120	9.5	9.15	1,575	1	400
" 7	6.35 p. m.	117	3.2	120	5.7	.08	16	2	5,000
" 7	6.45 p. m.	117	3.2	120	6.1	.25	48	1	1,200
" 7	7.00 p. m.	117	3.2	120	6.2	.50	96	1	300
" 7	9.00 p. m.	117	3.2	120	7.5	2.50	473	1	325
" 7	11.00 p. m.	117	3.2	120	8.0	4.50	862	1	300
" 8	1.00 a. m.	117	3.2	120	9.5	6.50	1,243	1	220
" 8	2.23 a. m.	117	3.2	120	10.0	7.88	1,485	1	375
" 8	2.33 a. m.	117	3.2	120	10.0	8.05	1,510	1	325
" 8	3.00 a. m.	117	3.2	120	10.0	8.50	1,598	1	190
" 8	4.55 a. m.	118	3.2	120	5.9	.08	16	4	3,800
" 8	5.05 a. m.	118	3.2	120	6.0	.25	48	1	1,400
" 8	5.20 a. m.	118	3.2	120	6.2	.50	96	1	500
" 8	7.00 a. m.	118	3.2	120	7.9	2.17	411	1	325
" 8	9.00 a. m.	118	3.2	120	8.4	4.17	800	1	1,000
" 8	11.00 a. m.	118	3.2	120	9.0	6.17	1,184	1	2,700
" 8	12.40 p. m.	118	3.2	120	10.0	7.84	1,500	1	2,000
" 8	1.05 p. m.	118	3.2	120	10.0	8.26	1,545	1	6,500
" 8	1.15 p. m.	118	3.2	120	10.0	8.39	1,575	1	4,200
" 8	2.00 p. m.	118	3.2	120	10.0	9 00	1,678	1	3,600
" 8	2.20 p. m.	118	...	...	....	9.24	1,720	1	4,000
" 8	9.13 p. m.	119	3.2	120	....	.08	16	2	2,700
" 8	9.23 p. m.	119	3.2	120	....	.25	48	2	21,900
" 8	9.38 p. m.	119	3.2	120	....	.50	96	4	14,800
" 9	4.30 a. m.	120	3.2	120	....	.08	16	5	8,100
" 9	4.40 a. m.	120	3.2	120	....	.25	48	5	17,300
" 9	4.55 a. m.	120	3 2	120	....	.50	96	5	19,800
" 9	10 05 a. m.	121	3.2	120	....	.08	16	3	6,200
" 9	10.15 a. m.	121	3.2	120	....	.25	48	2	9,700
" 9	10.30 a. m.	121	3.2	120	....	.50	98	1	10,800
" 9	11.00 a. m.	121	3.2	120	6.8	1.00	192	1	12,100
" 9	12.00 m.	121	3.2	120	7.8	2 00	384	1	550
" 9	12.30 p. m.	121	3 2	120	7.9	2.50	480	1	550
" 9	1.10 p. m.	122	3.2	120	....	.08	16	4	4,000
" 9	1.20 p. m.	122	3.2	120	....	.25	48	2	5,300
" 9	1.35 p. m.	122	3.2	120	....	.50	96	1	4,200
" 9	4.00 p. m.	123	3.2	120	2.7	.09	16	3	5,600
" 9	4.10 p. m.	123	3.2	120	2.8	.25	48	2	7,100
" 9	4.25 p. m.	123	3.2	120	....	.50	96	1	4,100
" 9	6.00 p. m.	123	3.2	120	4.3	2.08	399	2	3,400
" 9	8.00 p. m.	123	3.2	120	4.8	4.08	787	4	5,500
" 9	10.00 p. m.	123	3.2	120	5.6	6.08	1,172	4	3,200
" 9	11.23 p. m.	124	3.2	120	....	.08	16	4	2,300
" 9	11.33 p. m.	124	3.2	120	....	.25	48	3	8,400

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours.	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
December 9	11.48 p. m.	124	3.2	120	3.7	.50	96	3	6,700
" 10	1.00 a. m.	124	3.2	120	4.1	1.70	328	2	3,100
" 10	3.00 a. m.	124	3.3	124	5.3	3.70	726	3	5,900
" 10	5.00 a. m.	124	3.2	120	....	5.70	1,109	3	4,000
" 10	6.10 a. m.	124	3.2	120	....	6.87	1,341	3	4,600
" 10	10.45 p. m.	125	3.2	120	3.6	.08	16	1	850
" 10	11.55 p. m.	125	3.2	120	4.3	.25	48	1	900
" 11	12.10 a. m.	125	3.2	120	....	.50	96	1	1,300
" 11	1.00 a. m.	125	3.3	124	4.4	2.33	458	1	1,800
" 11	3 00 a. m.	125	3.2	120	4.8	4.33	847	1	1,400
" 11	4.00 a. m.	126	3.2	120	3.4	.08	16	1	700
" 11	4.10 a. m.	126	3.2	120	3.5	.25	48	1	375
" 11	4.25 a. m.	126	3.2	120	3.5	.50	96	1	120
" 11	6.00 a. m.	126	3.2	120	4.0	2.08	408	1	120
" 11	8.00 a. m.	126	3.2	120	4.3	4.08	795	1	55
" 11	10.00 a. m.	126	3.2	120	5.0	6.08	1,180	1	275
" 11	12.00 m.	126	3.2	120	5.4	8.08	1,564	1	1,200
" 11	12.40 p. m.	127	3.2	120	3.0	.08	16	1	220
" 11	12.50 p. m.	127	3.2	120	3.2	.25	48	1	220
" 11	1.05 p. m.	127	3.2	120	3.4	.50	96	1	90
" 11	2.00 p. m.	127	3.2	120	3.5	1.42	274	1	70
" 11	4.00 p. m.	127	3.2	120	3.9	3.42	660	1	275
" 11	6.00 p. m.	127	3.2	120	4.6	5.42	1,038	2	110
" 11	8.00 p. m.	127	3.2	120	5.8	7.42	1,402	2	1,600
" 12	3.40 a. m.	128	3.2	120	3.4	.08	16	1	650
" 12	3.50 a. m.	128	3.2	120	3.5	.25	48	1	400
" 12	4.05 a. m.	128	3.2	120	3.7	.50	96	1	400
" 12	5.00 a. m.	128	3.2	120	4.2	1.42	269	1	210
" 12	7.00 a. m.	128	3.2	120	4.7	3.42	663	1	210
" 12	9.00 a. m.	128	3.2	120	5.4	5.42	1,049	1	200
" 12	11.00 a. m.	128	3.2	120	6.0	7.42	1,434	1	1,500
" 12	11.45 a. m.	129	3.2	120	....	.08	16	1	550
" 12	11.55 a. m.	129	3.2	120	....	.25	48	1	475
" 12	12.10 p. m.	129	3.2	120	3.3	.50	96	1	1,100
" 12	1.00 p. m.	129	3.2	120	3.6	1.33	252	1	450
" 12	3.00 p. m.	129	3.2	120	4.2	3.33	638	1	1,400
" 12	5.00 p. m.	129	3.2	120	4.4	5.33	1,024	1	800
" 12	7.00 p. m.	129	3.2	120	4.7	7.33	1,408	1	550
" 12	9.00 p. m.	129	3.2	120	5.9	9.33	1,792	1	850
" 12	10.40 p. m.	130	3.2	120	3.6	.08	16	1	750
" 12	10.50 p. m.	130	3.2	120	3.7	.25	48	1	450
" 12	11.15 p. m.	130	3.2	120	....	.50	96	1	500
" 12	12.00 p. m.	130	3.2	120	3.8	1.42	172	1	600
" 13	2.00 a. m.	130	3.2	120	4.4	3.42	659	1	400
" 13	4.00 a. m.	130	3.2	120	4.7	5.42	1,049	1	210
" 13	6.00 a. m.	130	3.2	120	5.3	7.42	1,443	1	170
" 13	6.30 a. m.	131	3.3	124	....	.08	16	1	400
" 13	6.40 a. m.	131	3.3	124	3.5	.25	48	1	200
" 13	6.55 a. m.	131	3.2	120	3.7	.50	96	1	130
" 13	8.00 a. m.	131	3.2	120	3.8	1.58	311	1	180
" 13	10.00 a. m.	131	3.3	124	3.9	3.58	691	1	60
" 13	12.00 m.	131	3.2	120	4.5	5.58	1,075	1	150
" 13	2.00 p. m.	131	3.2	120	4.9	7.58	1,460	1	275
" 13	4.00 p. m.	131	3.2	120	5.0	9.58	1,846	2	325
" 13	6.00 p. m.	131	3.2	120	5.5	11.58	2,233	2	425
" 13	7.03 p. m.	132	3.2	120	3.5	.08	16	1	300
" 13	7.13 p. m.	132	3.2	120	3.6	.23	48	1	250
" 13	7.28 p. m.	132	3.2	120	....	.50	96	1	325
" 13	9.00 p. m.	132	3.2	120	4.5	2.03	391	1	450
" 13	11.00 p. m.	132	3.2	120	4.7	4.03	778	1	450
" 14	1.00 a. m.	132	3.2	120	4.9	6 03	1,176	2	800
" 14	2.00 a. m.	132	3.2	120	5.6	7.03	1,375	2	700

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
December 14	2.25 a. m.	133	3.3	124	....	.08	16	2	800
" 14	2.35 a. m.	133	3.3	124	3.3	.25	48	1	800
" 14	2.50 a. m.	133	3.2	120	3.6	.50	96	1	550
" 14	4.00 a. m.	133	3.3	124	3.7	1.67	334	1	300
" 14	6.00 a. m.	133	3.2	120	3.8	3.67	722	1	250
" 14	8.00 a. m.	133	3.2	120	4.4	5.67	1,104	1	210
" 14	10.00 a. m.	133	3.2	120	4.4	7.67	1,488	1	95
" 14	12.00 m.	133	3.2	120	4.5	9.67	1,874	1	240
" 14	1.00 p. m.	133	3.2	120	4.9	10.67	2,104	1	220
" 14	4.40 p. m.	134	3.2	120	....	.08	16	4	600
" 14	4.50 p. m.	134	3.2	120	....	.25	48	2	450
" 14	5.05 p. m.	134	3.2	120	5.5	.50	96	1	325
" 14	7.00 p. m.	134	3.2	120	6.7	2.42	455	1	375
" 14	9.00 p. m.	134	3.2	120	7.8	4.42	839	1	325
" 14	11.00 p. m.	134	3.2	120	8.8	6.42	1,223	1	300
" 14	12 00 p. m.	134	3.2	120	10.1	7.42	1,413	1	325
" 15	12.32 a. m.	135	3.2	120	....	.08	16	2	550
" 15	12.42 a. m.	135	3.2	120	6.5	.25	48	1	350
" 15	12.57 a. m.	135	3.2	120	6.7	.50	96	1	550
" 15	2.00 a. m.	135	3.3	124	6.9	1.55	301	1	350
" 15	4.00 a. m.	135	3.2	120	7.4	3.55	685	1	375
" 15	6.00 a. m.	135	3.2	120	8.2	5.55	1,071	1	300
" 15	8.00 a. m.	135	3.2	120	9.6	7.55	1,456	1	425
" 15	9.52 a. m.	136	3.2	120	6.5	.08	16	2	475
" 15	10.02 a. m.	136	3.2	120	6.5	.25	48	2	350
" 15	10.17 a. m.	136	3.2	120	....	.50	96	1	325
" 15	12.00 m.	136	3.2	120	7.6	2.22	424	1	210
" 15	2.00 p. m.	136	3.2	120	8.5	4.22	808	1	275
" 15	4.00 p. m.	136	3.1	116	9.5	6.22	1,174	1	250
" 15	7.11 p. m.	137	3.2	120	6.5	.08	16	2	1,600
" 15	7.20 p. m.	137	3.2	120	6.7	.25	48	1	550
" 15	7.36 p. m.	137	3.2	120	7.0	.50	96	1	325
" 15	9.00 p. m.	137	3.2	120	7.7	1.90	363	1	325
" 15	11.00 p. m.	137	3.2	120	9.5	3.90	738	1	130
" 15	12.00 p. m.	137	3.2	120	10.0	4.90	923	1	250
" 16	12.37 a. m.	138	3.2	120	6.4	.08	16	2	800
" 16	12.47 a. m.	138	3.2	120	6.5	.25	48	1	425
" 16	1.00 a. m.	138	3.2	120	6.5	.50	96	1	220
" 16	3.00 a. m.	138	3.2	120	7.3	2.47	473	1	140
" 16	5.00 a. m.	138	3.2	120	8.5	4.47	855	1	150
" 16	7.00 a. m.	138	3.2	120	9.9	6.47	1,238	2	190
" 16	7.30 a. m.	139	3.2	120	6.0	.08	16	2	1,100
" 16	7.40 a. m.	139	3.2	120	6.3	.25	48	1	325
" 16	7.55 a. m.	139	3.2	120	6.3	.50	96	1	275
" 16	9.00 a. m.	139	3.2	120	6.3	1.58	297	1	230
" 16	11.00 a. m.	139	3.2	120	7.5	3.58	681	1	300
" 16	1.00 p. m.	139	3.2	120	9.0	5.58	1,065	1	400
" 16	3.39 p. m.	140	3.2	120	6.5	.08	16	2	425
" 16	3.49 p. m.	140	3.2	120	6.7	.25	48	1	550
" 16	4.04 p. m.	140	3.2	120	6.8	.50	96	1	250
" 16	5.00 p. m.	140	3.2	120	7.4	1.43	280	1	300
" 16	7.00 p. m.	140	3.2	120	8.4	3.43	665	1	210
" 16	9.00 p. m.	140	3.2	120	9.5	5.43	1,048	1	220
" 16	10.00 p. m.	140	3.2	120	10.0	6.43	1,240	1	220
" 16	10.35 p. m.	141	3.2	120	6.6	.08	16	2	1,400
" 16	10.45 p. m.	141	3.2	120	6.7	.25	48	1	1,000
" 16	11.00 p. m.	141	3.2	120	6.7	.50	96	1	300
" 16	12.00 p. m.	141	3.2	120	7.1	1.50	290	1	425
" 17	2 00 a. m.	141	3.2	120	8.2	3.50	674	1	160
" 17	4.00 a. m.	141	3.2	120	9.2	5.50	1,157	1	275
" 17	5.30 a. m.	141	3.2	120	10.0	7.00	1,347	1	275
" 17	6.05 a. m.	142	3.2	120	6.3	.08	16	1	1,100

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
December 17	6.15 a. m.	142	3.2	120	6.4	.25	48	1	375
" 17	6.30 a. m.	142	3.2	120	6.4	.50	96	1	550
" 17	8.00 a. m.	142	3.2	120	6.7	2.00	386	1	220
" 17	10 00 a. m.	142	3.2	120	7.7	4.00	775	1	300
" 17	12.00 m.	142	3.2	120	8.2	6.00	1,156	2	400
" 17	2.00 p. m.	142	3.2	120	10.0	8.00	1,540	1	240
" 17	9.10 p. m.	143	3.2	120	6.5	.08	16	2	1,300
" 17	9.20 p. m.	143	3.2	120	6.6	.25	48	1	1,200
" 17	9.35 p. m.	143	3.2	120	6.7	.50	96	2	400
" 17	11.00 p. m.	143	3.2	120	7.5	1.92	370	1	200
" 18	1.00 a. m.	143	3.2	120	8.2	3.92	754	1	375
" 18	3 00 a. m.	143	3.2	120	9.3	5.92	1,138	1	300
" 18	4.30 a. m.	143	3.2	120	10.0	7.42	1,425	2	250
" 18	5.05 a. m.	144	3.2	120	6.5	.08	16	2	1,200
" 18	5.15 a. m.	144	3.2	120	6.7	.23	48	1	300
" 18	5.30 a. m.	144	3.2	120	6.8	.50	96	1	400
" 18	7.00 a. m.	144	3.2	120	7.4	2.00	381	1	230
" 18	9.00 a. m.	144	3.2	120	7.5	4.00	765	1	325
" 18	11.00 a. m.	144	3.2	120	8.6	6.00	1,149	1	325
" 18	1.00 p. m.	144	3.2	120	10.0	8.00	1,533	2	250
" 18	6.10 p. m.	145	3.2	120	6.6	.08	16	1	850
" 18	6.20 p. m.	145	3.2	120	6.7	.25	48	1	375
" 18	6 35 p. m.	145	3.2	120	6.8	.50	96	1	325
" 18	8.00 p. m.	145	3.2	120	7.5	1.92	371	1	230
" 18	10 00 p. m.	145	3.2	120	8.2	3.92	758	1	275
" 18	12.00 p. m.	145	3.2	120	9.2	5.92	1,140	1	275
" 19	2.00 a. m.	145	3.2	120	10.0	7.92	1,523	1	275
" 19	2.35 a. m.	146	3.2	120	6.3	.08	16	2	500
" 19	2.45 a. m.	146	3.2	120	6.3	.25	48	2	400
" 19	3.00 a. m.	146	3.2	120	6 4	.50	96	1	400
" 19	5.00 a. m.	146	3.2	120	7.1	2.50	480	1	300
" 19	7.00 a. m.	146	3.2	120	7.6	4.50	862	1	375
" 19	9.00 a. m.	146	3.2	120	8.8	6.50	1,248	1	200
" 19	11.00 a. m.	146	8 2	120	9.4	8.50	1,632	1	200
" 19	12.48 p. m.	147	3.2	120	6.0	.08	16	1	1,000
" 19	12.58 p. m.	147	3.2	120	6.1	.25	48	1	400
" 19	1.17 p. m.	147	3.2	120	7.4	.50	96	1	325
" 19	3.00 p. m.	147	3.2	120	7.8	2.28	426	1	170
" 19	5.00 p. m.	147	3.2	120	9.6	4.28	798	1	275
" 19	6.00 p. m.	147	3.2	120	10.0	5.28	992	1	325
" 19	11.10 p. m.	148	3.2	120	6.6	.08	16	2	600
" 19	11.20 p. m.	148	3.2	120	6.8	.25	48	1	325
" 19	11.35 p. m.	148	3.2	120	7.0	.50	96	1	375
" 20	1.00 a. m.	148	3.2	120	7.6	1.92	372	2	250
" 20	3.00 a. m.	148	3.2	120	8.6	3.92	756	1	325
" 20	5.00 a. m.	148	3.2	120	10.0	5.92	1,138	1	375
" 20	5.35 a. m.	149	3.2	120	6.3	.08	16	2	475
" 20	5.45 a. m.	149	3.2	120	6.5	.25	48	2	425
" 20	6.00 a. m.	149	3.2	120	6.5	.50	96	1	425
" 20	8 00 a. m.	149	3.2	120	6.8	2.50	481	1	375
" 20	10.00 a. m.	149	3.2	120	7.7	4.50	865	1	130
" 20	12.00 m.	149	3.2	120	9.3	6 50	1,249	1	160
" 20	2.00 p. m.	149	3.2	120	9.6	8.50	1,643	1	180
" 20	3.39 p. m.	150	3 2	120	6.3	.08	16	3	800
" 20	3.49 p. m.	150	3.2	120	6.4	.25	48	1	550
" 20	4.04 p. m.	150	3.2	120	6.7	.50	96	1	300
" 20	6.00 p. m.	150	3.2	120	8.1	2.43	468	1	425
" 20	8.00 p. m.	150	3.2	120	9.5	4.43	855	1	220
" 20	10.00 p. m.	150	3.2	120	10.0	6.43	1,239	1	300
" 20	10.40 p. m.	151	3.2	120	6.3	.08	16	1	600
" 20	10.50 p. m.	151	3.2	120	6.5	.25	48	2	350
" 20	11.05 p. m.	151	3.2	120	6.5	.50	96	1	425

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
December 21	1.00 a. m.	151	3.2	120	7.3	2.42	465	1	400
" 21	3.00 a. m.	151	3.2	120	8.2	4.42	849	1	425
" 21	5.00 a. m.	151	3.2	120	9.4	6.42	1,231	1	350
" 21	6.00 a. m.	151	3.2	120	10.0	7.42	1,422	1	400
" 21	6.35 a. m.	152	3.2	120	6.1	.08	16	2	600
" 21	6.45 a. m.	152	3.2	120	6.3	.25	48	1	600
" 21	7.00 a. m.	152	3.2	120	6.3	.50	96	1	550
" 21	9.00 a. m.	152	3.2	120	6.9	2.50	480	1	275
" 21	11.00 a. m.	152	3.2	120	7.4	4.50	864	1	400
" 21	1.00 p. m.	152	3.2	120	7.9	6.50	1,248	1	550
" 21	3.00 p. m.	152	3.2	120	9.3	8.50	1,632	1	200
" 21	4.45 p. m.	153	3.2	120	6.4	.08	16	2	750
" 21	4.55 p. m.	153	3.2	120	6.5	.25	48	1	350
" 21	5.10 p. m.	153	3.2	120	6.7	.50	96	1	425
" 21	7.00 p. m.	153	3.2	120	7.6	2.33	464	1	210
" 21	9.00 p. m.	153	3.2	120	8.4	4.33	848	1	375
" 21	11.00 p. m.	153	3.2	120	9.6	6.33	1,228	1	450
" 22	1.00 a. m.	153	3.2	120	10.1	8.33	1,604	1	325
" 22	1.35 a. m.	154	3.2	120	6.0	.08	16	2	750
" 22	1.45 a. m.	154	3.2	120	6.1	.25	48	1	13,500
" 22	2.00 a. m.	154	3.2	120	6.2	.50	96	1	650
" 22	4.00 a. m.	154	3.2	120	6.6	2.50	481	1	2,000
" 22	6.00 a. m.	154	3.2	120	7.1	4.50	866	1	3,600
" 22	8.00 a. m	154	3.2	120	8.2	6.50	1,250	1	4,000
" 22	10.00 a. m.	154	3.2	120	9.2	8.50	1,634	1	2,300
" 22	12.00 m.	154	3.2	120	10.0	10.50	2,018	1	1,400
" 22	3.45 p. m.	155	3.2	120	4.3	.08	16	1	11,000
" 22	3.55 p. m.	155	3.2	120	4.4	.25	48	1	10,500
" 22	4.10 p. m.	155	3.2	120	4.4	.50	96	1	9,500
" 22	6.00 p. m.	155	3.2	120	4.8	2.33	458	1	6,900
" 22	8.00 p. m.	155	3.2	120	5.3	4.33	843	1	8,200
" 22	10.00 p. m.	155	3.3	120	6.3	6.33	1,233	1	10,100
" 22	12.00 p. m.	155	3.2	120	6.9	8.33	1,618	1	9,200
" 23	2.00 a. m.	155	3.2	120	8.1	10.33	2,002	1	7,700
" 23	4.00 a. m.	155	3.2	120	9.8	12.33	2,387	1	7,000
" 23	5.00 a. m.	155	3.2	120	10.2	13.33	2,578	1	10,700
" 23	5.35 a. m.	156	3.2	120	4.0	.08	16	2	8,600
" 23	5.45 a. m.	156	3.2	120	4.1	.25	48	2	10,400
" 23	6.00 a. m.	156	3.2	120	4.1	.50	96	1	10,300
" 23	8.00 a. m.	156	3.2	120	4.4	2.50	481	1	8,100
" 23	10.00 a. m.	156	3.2	120	5.9	4.50	865	1	5,100
" 23	12.00 m.	156	3.2	120	6.7	6.50	1,249	1	6,100
" 23	2.00 p. m.	156	3.2	120	7.2	8.50	1,630	2	8,100
" 23	4.00 p. m.	156	3.2	120	8.8	10.50	2,022	2	6,700
" 24	9.36 a. m.	157	3.2	120	....	.08	16	3	2,600
" 24	9.48 a. m.	157	3.2	120	3.9	.25	48	2	2,600
" 24	10.03 a. m.	157	3.2	120	3.9	.50	96	2	3,400
" 24	7.15 p. m.	158	3.2	120	....	.08	16	4	3,700
" 24	7.25 p. m.	158	3.2	120	5.0	.25	48	2	2,600
" 24	7.40 p. m.	158	3.2	120	5.2	.50	96	2	1,100
" 24	9.00 p. m.	158	3.2	120	5.7	1.83	353	1	375
" 24	11.00 p. m.	158	3.2	120	7.2	3.83	740	1	550
" 25	1.00 a. m.	158	3.2	120	8.9	5.83	1,122	1	750
" 25	3.00 a. m.	158	3.2	120	10.2	7.83	1,506	1	180
" 25	4.35 a. m.	159	3.2	120	4.4	.08	16	1	2,600
" 25	4.45 a. m.	159	3.2	120	....	.25	48	1	2,700
" 25	5.00 a. m.	159	3.2	120	....	.50	96	1	650
" 25	7.00 a. m.	159	3.2	120	5.9	2.50	481	1	325
" 25	9.00 a. m.	159	3.2	120	8.7	4.50	865	1	400
" 25	12.08 p. m.	160	3.2	120	....	.08	16	1	2,200
" 25	12.18 p. m.	160	3.2	120	....	.25	48	1	2,500
" 25	12.33 p. m.	160	3.2	120	5.8	.50	96	1	1,800

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected. Date—1898.	Hour.	Number of Run.	Rate of Filtration. Cubic Feet per Minute.	Rate of Filtration. Million Gallons per Acre per 24 Hours.	Loss of Head. Feet.	Period of Service since Last Washing. Hours	Filtered Water since Last Washing. Cubic Feet.	Degree of Clearness.	Bacteria per Cubic Centimeter.
December 25	2.00 p. m.	160	3.2	120	6.6	1.95	367	1	300
" 25	4.00 p. m.	160	3.2	120	8.0	3.95	750	1	190
" 25	6.00 p. m.	160	3.2	120	9.8	5.95	1,136	1	250
" 25	7.40 p. m.	161	3.2	120	6.5	.08	16	1	1,300
" 25	7.50 p. m.	161	3.2	120	6.6	.25	48	1	850
" 25	8.05 p. m.	161	3.2	120	6.8	.50	96	1	600
" 25	10.00 p. m.	161	3.2	120	5.9	2.42	483	1	400
" 25	12.00 m.	161	3.2	120	7.0	4.42	865	1	425
" 26	2.00 a. m.	161	3.2	120	7.4	6.44	249	1	400
" 26	4.00 a. m.	161	3.2	120	8.1	8.44	633	1	300
" 26	6.00 a. m.	161	3.2	120	9.2	10.42	2,017	1	250
" 26	7.00 a. m.	161	2.2	120	10.0	11.42	2,209	1	300
" 26	7.35 a. m.	162	3.2	120	5.0	.08	16	1	425
" 26	7.45 a. m.	162	3.2	120	5.1	.25	48	1	500
" 26	8.00 a. m.	162	3.2	120	5.3	.50	96	1	600
" 26	10.00 a. m.	162	3.2	120	5.7	2.50	482	1	325
" 26	12.00 m.	162	3.2	120	6.1	4.50	866	1	130
" 26	2.00 p. m.	162	3.2	120	6.5	6.50	1,250	1	100
" 26	4.00 p. m.	162	3.2	120	8.3	8.50	1,617	1	210
" 26	6.00 p. m.	162	3.2	120	8.7	10.50	2,001	1	250
" 26	8.00 p. m.	162	3.2	120	9.8	12.50	2,385	1	250
" 26	9.40 p. m.	163	3.2	120	5.5	.08	16	1	1,400
" 26	9.50 p. m.	163	3.2	120	5.5	.25	48	1	550
" 26	10.05 p. m.	163	3.2	120	5.6	.50	96	1	350
" 26	12.00 p. m.	163	3.2	120	6.3	2.42	468	1	425
" 27	2.00 a. m.	163	3.2	120	6.8	4.42	853	1	230
27	4.00 a. m.	163	3.2	120	7.4	6.42	1,236	1	275
" 27	6.00 a. m.	163	3.2	120	7.8	8.42	1,621	1	210
" 27	8.00 a. m.	163	3.2	120	8.3	10.42	2,005	1	230
" 27	10.58 a. m.	164	3.2	120	5.0	.08	16	1	425
" 27	11.08 a. m.	164	3.2	120	5.2	.25	48	1	375
" 27	11.23 a. m.	164	3.2	120	5.5	.50	96	1	200
" 27	1.00 p. m.	164	3.2	120	6.6	2.12	409	1	140
" 27	3.00 p. m.	164	3.2	120	7.1	4.12	793	1	160
" 27	5.00 p. m.	164	3.2	120	8.1	6.12	1,191	1	160
27	7.00 p. m.	164	3.2	120	8.6	8.12	1,578	1	130
" 27	9.00 p. m.	164	3.2	120	9.6	10.12	1,960	1	130
" 27	10.10 p. m.	165	3.2	120	5.0	.08	16	1	600
" 27	10.20 p. m.	165	3.2	120	5.2	.25	48	1	210
" 27	10.35 p. m.	165	3.3	124	5.5	.50	96	1	180
" 27	12.00 p. m.	165	3.2	120	6.2	1.92	375	1	140
" 28	2.00 a. m.	165	3.2	120	6.7	3.92	760	1	80
" 28	4.00 a. m.	165	3.3	124	7.3	5.92	1,145	1	80
" 28	6.00 a. m.	165	3.2	120	7.6	7.92	1,529	1	65
" 28	8.00 a. m.	165	3.2	120	9.3	9.92	1,913	1	80
" 28	10.00 a. m.	165	3.2	120	10.0	11.92	2,287	1	50
" 28	10.55 a. m.	166	3.2	120	....	.08	16	1	400
" 28	11.05 a. m.	166	3.2	120	5.7	.25	48	1	160
" 28	11.20 a. m.	166	3.2	120	....	.50	96	1	70
" 29	5.35 a. m.	167	3.2	120	5.0	.08	16	2	100
" 29	5.45 a. m.	167	3.2	120	5.1	.25	48	1	70
" 29	6.00 a. m.	167	3.3	124	5.1	.50	96	1	70
" 29	8.00 a. m.	167	3.2	120	6.0	2.50	488	2	60
" 29	10.00 a. m.	167	3.2	120	6.4	4.50	884	1	38
" 29	12.00 m.	167	3.2	120	7.1	6.50	1,269	1	38
" 29	2.00 p. m.	167	3.2	120	8.2	8.50	1,658	1	40
" 29	4.00 p. m.	167	3.2	120	8.8	10.50	2,044	1	29
" 29	6.00 p. m.	167	3.2	120	10.0	12.50	2,428	1	18
" 30	12.39 a. m.	168	3.3	124	4.7	.08	16	1	200
" 30	12.49 a. m.	168	3.2	120	4.8	.25	48	1	95
" 30	1.04 a. m.	168	3.2	120	5.0	.50	96	1	65
" 30	3.00 a. m.	168	3.2	120	6.5	2.43	464	1	25

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1898.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
December 30	5.00 a. m.	168	3.2	120	8.1	4.43	869	1	42
" 30	7.00 a. m.	168	3.2	120	10.0	6.43	1,210	1	41
" 30	7.50 a. m.	169	3.2	120	5.0	.08	16	1	400
" 30	8.00 a. m.	169	3.2	120	5.3	.25	48	1	325
" 30	8.15 a. m.	169	3.2	120	5.5	.50	96	1	100
" 30	10.00 a. m.	169	3.2	120	6.9	2.25	433	1	55
" 30	12.00 m.	169	3.2	120	8.6	4.25	818	2	46
" 30	1.20 p. m.	169	3.2	120	9.6	5.55	1,065	2	33
" 30	2.00 p. m.	170	4.4	165	7.4	.08	19	1	500
" 30	2.10 p. m.	170	4.4	165	7.5	.25	63	1	190
" 30	2.25 p. m.	170	4.4	165	7.8	.50	129	1	120
" 30	4.00 p. m.	170	4.1	154	9.3	2.08	517	1	70
" 30	5.00 p. m.	170	3.8	142	10.1	3.08	748	1	60
" 30	5.40 p. m.	171	4.4	165	6.8	.08	22	1	275
" 30	5.50 p. m.	171	4.4	165	6.9	.25	66	1	95
" 30	6.05 p. m.	171	4.4	165	7.2	.50	129	1	80
" 30	7.00 p. m.	171	4.4	165	8.2	1.42	374	1	32
" 30	8.00 p. m.	171	4.1	154	9.2	2.42	632	1	32
" 30	9.00 p. m.	171	3.8	142	10.0	3.42	867	1	29
" 30	11.05 p. m.	172	1.3	49	....	.08	6	4	350
" 30	11.15 p. m.	172	1.3	49	....	.25	20	2	325
" 30	11.30 p. m.	172	1.3	49	1.8	.50	39	1	450
" 31	1.00 a. m.	172	1.3	49	2.5	2.00	159	1	160
" 31	3.00 a. m.	172	1.3	49	3.0	4.00	319	2	20
" 31	5.00 a. m.	172	1.3	49	3.2	6.00	479	1	15
" 31	7.00 a. m.	172	1.3	49	3.4	8.00	639	1	38
" 31	9.00 a. m.	172	1.2	45	4.3	10.00	794	1	40
" 31	11.00 a. m.	172	1.2	45	4.9	12.00	951	1	12
" 31	1.00 p. m.	172	1.3	49	5.2	14.00	1,150	1	23
" 31	3.00 p. m.	172	1.3	49	5.4	16.00	1,249	1	22
" 31	5.00 p. m.	172	1.3	49	5.8	18.00	1,408	1	16
" 31	7.00 p. m.	172	1.3	49	6.4	20.00	1,570	1	8
" 31	9.00 p. m.	172	1.3	49	6.6	22.00	1,729	1	14
" 31	11.00 p. m.	172	1.3	49	6.8	24.00	1,889	1	11
January ('99) 1	1.00 a. m.	172	1.3	49	6.8	26.00	2,049	1	9
" 1	3.00 a. m.	172	1.3	49	7.0	28.00	2,180	1	9
" 1	5.00 a. m.	172	1.3	49	....	30.00	2,256	1	7
" 1	6.24 a. m.	173	1.3	49	2.8	.08	6	1	190
" 1	6.34 a. m.	173	1.3	49	2.8	.25	20	1	140
" 1	6.49 a. m.	173	1.3	49	2.9	.50	33	1	75
" 1	8.00 a. m.	173	1.3	49	4.2	1.68	130	1	25
" 1	10.00 a. m.	173	1.3	49	3.7	3.68	294	1	13
" 1	12.00 m.	173	1.3	49	4.3	5.68	470	1	12
" 1	2.00 p. m.	173	1.3	49	4.7	7.68	628	1	9
" 1	4.00 p. m.	173	1.3	49	5.3	9.68	785	1	19
" 1	6.00 p. m.	173	1.3	49	6.6	11.68	955	1	11
" 1	8.00 p. m.	173	1.3	49	7.8	13.68	1,117	1	7
" 1	10.00 p. m.	173	1.3	49	9.2	15.68	1,274	1	6
" 1	11.00 p. m.	173	1.3	49	10.0	16.68	1,364	1	19
" 2	6.08 a. m.	174	3.2	120	....	.08	16	1	550
" 2	6.18 a. m.	174	3.2	120	....	.25	48	1	150
" 2	6.33 a. m.	174	3.2	120	5.5	.50	96	1	140
" 2	8.00 a. m.	174	3.2	120	5.8	....	....	1	70
" 2	10.00 a. m.	174	3.2	120	8.4	.75	149	1	34
" 2	12.00 m.	174	3.2	120	9.6	1.75	529	1	43
" 2	1.00 p. m.	174	3.2	120	10.0	3.75	720	1	35
" 2	7.10 p. m.	175	3.2	120	....	.08	16	1	35
" 2	7.20 p. m.	175	3.2	120	....	.25	48	1	34
" 2	7.35 p. m.	175	3.2	120	5.5	.50	96	1	37
" 2	9.00 p. m.	175	3.2	120	5.8	1.92	384	1	75
" 2	11.00 p. m.	175	3.2	120	6.4	3.92	768	1	55
" 3	1.00 a. m.	175	3.2	120	6.9	5.92	1,155	1	110

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.			Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.		Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January	3.....	3.00 a. m.	175	3.2	120	7.5	7.92	1,539	1	75
..	3.....	5.00 a. m.	175	3.2	120	9.5	9.92	1,918	1	50
..	3.....	6.45 a. m.	176	4.0	150	....	.08	20	1	400
..	3.....	6.55 a. m.	176	4.0	150	7.3	.25	60	1	350
..	3.....	7.10 a. m.	176	4.0	150	....	.50	120	1	275
..	3.....	8.00 a. m.	176	4.0	150	7.9	1.33	329	1	325
..	3.....	10.00 a. m.	176	4.0	150	9.1	3.33	827	1	275
..	3	12.00 m.	176	4.0	150	9.7	5.33	1,069	1	250
..	3	1.00 p. m.	176	4.0	150	10.0	6.33	1,527	1	200
..	3.....	1.35 p. m.	177	3.2	120	5.3	.08	16	1	250
..	3.....	1.45 p. m.	177	3.2	120	5.3	.25	48	1	275
..	3.....	2.00 p. m.	177	3.2	120	5.4	.50	96	1	325
..	3.....	4.00 p. m.	177	3.2	120	5.5	2 50	482	1	350
..	3.....	6.00 p. m.	177	3.2	120	6.1	4.50	866	1	65
..	3.....	8.00 p. m.	177	3.2	120	6.5	6.50	1,250	1	70
..	3.....	10.00 p. m.	177	3 2	120	7.2	8.50	1,633	1	24
..	3.....	12.00 p. m.	177	3.2	120	8.4	10.50	2,018	1	8
..	4.....	2.00 a. m.	177	3.2	120	9.3	12.50	2,402	1	19
..	4.....	3.50 a. m.	178	3.2	120	5.3	.08	16	1	400
..	4.....	4.00 a. m.	178	3.2	120	5.3	.25	48	1	140
..	4.....	4.15 a. m.	178	3.2	120	5.4	.50	96	1	9
..	4.....	6.00 a. m.	178	3.2	120	5.9	2.25	430	1	35
..	4	8.00 a. m.	178	3.2	120	7.0	4.25	815	1	48
..	4.....	10.00 a. m.	178	3.2	120	8.1	6.25	1,201	1	26
..	4.....	12.00 m.	178	3.2	120	9.0	8.25	1,590	1	29
..	4.....	2.00 p. m.	178	3.2	120	10.1	10.25	1,976	1	60
..	4.....	2.39 p. m.	179	3.2	120	....	.08	16	1	200
..	4.....	2.49 p. m.	179	3.2	120	....	.25	48	1	250
..	4.....	3.07 p. m.	179	3.2	120	5.0	.50	96	1	210
..	4.....	5.00 p. m.	179	3.2	120	5.6	2.43	471	1	220
..	4.....	7.00 p. m.	179	3.2	120	6.0	4.43	855	1	275
..	4.....	9.00 p. m.	179	3.2	120	7.0	6.43	1,238	1	325
..	4.....	11.00 p. m.	179	3.2	120	8.0	8.45	1,623	1	275
..	5.....	1.00 a. m.	179	3.2	120	9.4	10.45	2,006	1	190
..	5.....	2.48 a. m.	180	3.2	120	5.0	.08	16	1	350
..	5.....	2.58 a. m.	180	3.2	120	5.0	.25	48	1	220
..	5.....	3.13 a. m.	180	3.2	120	....	.50	96	1	140
..	5	5.00 a. m.	180	3.2	120	5.7	2.28	437	1	350
..	5.....	7.00 a. m.	180	3.2	120	6.9	4.28	821	1	850
..	5.....	2.55 p. m.	181	3.2	120	4.9	.08	16	2	1,700
..	5.....	3.05 p. m.	181	3.2	120	4.9	.25	48	2	1,000
..	5.....	3.20 p. m.	181	3.2	120	....	.50	96	1	1,000
..	5.....	5.00 p. m.	181	3.2	120	6.4	2.17	417	1	375
..	5.....	7.00 p. m.	181	3.2	120	7.3	4.17	801	1	110
..	5.....	9.00 p. m.	181	3.2	120	8.2	6.17	1,183	1	30
..	5.....	11.00 p. m.	181	3 2	120	9.9	8.17	1,564	1	95
..	5.....	11 35 p. m.	182	3.2	120	4.9	.08	16	2	550
..	5	11.45 p. m.	182	3.2	120	5.0	.25	48	1	375
..	5.....	12.00 p. m.	182	3.2	120	....	.50	96	1	325
..	6.....	2.00 a. m.	182	3.2	120	5.5	2.50	480	1	170
..	6.....	4.00 a. m.	182	3.2	120	5.9	4.50	864	1	180
..	6	6.00 a. m.	182	3.2	120	6.3	6.50	1,248	1	150
..	6.....	8.00 a. m.	182	3.2	120	6.8	8.50	1,636	1	275
..	6.....	10.00 a. m.	182	3.2	120	7.9	10.50	2,021	1	210
..	6.....	12.00 m.	182	3.2	120	8.7	12.50	2,408	1	80
..	6.....	2.00 p. m.	182	3.2	120	9.7	14.50	2,793	1	275
..	6.....	2.15 p. m.	182	3.2	120	10.0	14.75	2,844	1	300
..	6.....	8.25 p. m.	183	3.2	120	5.0	.08	16	1	450
..	6.....	8.35 p. m.	183	3.2	120	5.1	.25	48	1	1,000
..	6.....	8.50 p. m.	183	3.2	120	5.2	.50	96	1	650
..	6	11.00 p. m.	183	3.2	120	6.1	2.67	511	1	800
..	7	1.00 a. m.	183	3.2	120	9.3	4.67	893	1	200

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.			Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.		Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January	7..	9.10 a. m.	184	3.2	120	5.3	.08	16	1	1,800
..	7.....	9.20 a. m.	184	3.2	120	5.5	.25	48	2	2,000
..	7.....	9.35 a. m.	184	3.2	120	5.7	.50	96	1	1,900
..	7.....	11.00 a. m.	184	3.2	120	7.0	1.92	370	1	1,300
..	7.....	1.00 p. m.	184	3.2	120	8.5	3.92	711	1	350
..	7.....	2.40 p. m.	184	3.2	120	10.0	5.59	1,062	1	300
..	7.....	3.15 p. m.	185	3.2	120	5.1	.08	16	2	650
..	7.....	3.25 p. m.	185	3.2	120	5.2	.25	48	1	950
..	7.....	3.40 p. m.	185	3.2	120	5.4	.50	96	1	600
..	7.....	5.00 p. m.	185	3.2	120	5.8	1.83	348	1	170
..	7.....	7.00 p. m.	185	3.2	120	7.0	3.83	732	1	14
..	7.....	9.00 p. m.	185	3.2	120	8.4	5.83	1,115	1	170
..	7.....	10.30 p. m.	185	3.2	120	10.1	7.33	1,400	1	250
..	7.....	11.05 p. m.	186	3.2	120	4.9	.08	16	1	650
..	7.....	11.15 p. m.	186	3.2	120	5.1	.25	48	1	750
..	7.....	11.30 p. m.	186	3.2	120	....	.50	96	1	550
..	8.....	1.00 a. m.	186	3.2	120	5.7	2.00	384	1	900
..	8..	3.00 a. m.	186	3.2	120	6.3	4.00	768	1	180
..	8.....	5.00 a. m.	186	3.2	120	8.1	6.00	1,152	1	130
..	8.....	7.00 a. m.	186	3.2	120	8.8	8.00	1,536	2	230
..	8.....	9.00 a. m.	186	3.2	120	9.4	10.00	1,920	1	190
..	8.....	10.00 a. m.	186	3.2	120	10.0	11.00	2,112	2	325
..	8..	10.35 a. m.	187	3.2	120	5.0	.08	16	2	700
..	8.....	10.45 a. m.	187	3.2	120	5.1	.25	48	1	300
..	8.....	11.00 a. m.	187	3.2	120	5.2	.50	96	1	500
..	8.....	12.00 m.	187	3.2	120	5.8	1.50	286	1	110
..	8.....	2.00 p. m.	187	3.2	120	6.3	3.50	674	1	250
..	8.....	4.00 p. m.	187	3.2	120	7.0	5.50	1,060	1	375
..	8.....	6.00 p. m.	187	3.2	120	7.7	7.50	1,444	1	100
..	8.....	8.00 p. m.	187	3.2	120	9.0	9.50	1,828	2	160
..	8.....	10.00 p. m.	187	3.2	120	9.6	11.50	2,214	1	130
..	8.....	11.00 p. m.	187	3.2	120	10.0	12.50	2,404	2	325
..	8.....	11.35 p. m.	188	3.2	120	4.7	.08	16	1	550
..	8.....	11.45 p. m.	188	3.2	120	4.8	.25	48	1	300
..	8.....	12.00 p. m.	188	3.2	120	4.8	.50	96	1	250
..	9.....	2.00 a. m.	188	3.2	120	5.2	2.50	480	1	140
..	9.....	4.00 a. m.	188	3.2	120	6.0	4.50	864	1	110
..	9.....	6.00 a. m.	188	3.2	120	7.2	6.50	1,248	1	90
..	9.....	8.00 a. m.	188	3.2	120	7.9	8.50	1,632	1	42
..	9.....	10.00 a. m.	188	3.2	120	9.0	10.50	2,020	1	37
..	9.....	11.00 a. m.	188	3.2	120	10.0	11.50	2,207	1	28
..	9.....	11.40 a. m.	189	3.2	120	5.2	.08	16	1	325
..	9.....	11.50 a. m.	189	3.2	120	5.3	.25	48	1	170
..	9.....	12.05 p. m.	189	3.2	120	5.4	.50	96	1	85
..	9.....	2.00 p. m.	189	3.3	124	6.4	2.42	474	1	60
..	9.....	4.00 p. m.	189	3.2	120	7.0	4.42	861	1	210
..	9.....	6.00 p. m.	189	3.2	120	7.6	6.42	1,243	1	100
..	9.....	8.00 p. m.	189	3.2	120	9.0	8.42	1,627	1	140
..	9.....	10.00 p. m.	189	3.2	120	10.0	10.42	2,010	1	80
..	9.....	10.35 p. m.	190	3.2	120	5.1	.08	16	1	375
..	9.....	10.45 p. m.	190	3.2	120	5.2	.25	48	1	275
..	9.....	11.00 p. m.	190	3.2	120	5.3	.50	96	1	250
..	10.....	1.00 a. m.	190	3.2	120	5.7	2.50	480	1	150
..	10.....	3.00 a. m.	190	3.2	120	6 2	4.50	864	1	65
..	10.....	5.00 a. m.	190	3.2	120	7.2	6.50	1,248	1	140
..	10.....	7.00 a. m.	190	3.2	120	8.6	8.50	1,632	1	150
..	10.....	9.00 a. m.	190	3.2	120	9.1	10.50	2,018	1	140
..	10.....	10.00 a. m.	190	3 2	120	10.0	11.50	2,210	....	90
..	10.....	10.36 a. m.	191	3.2	120	5.2	.08	16	....	350
..	10.....	10.46 a. m.	191	3.2	120	5.3	.25	48	....	180
..	10.....	11.00 a. m.	191	3.2	120	5.4	.48	96	....	250
..	10.....	12.00 m.	191	3.2	120	5.6	1.48	294	....	190

Results of Bacterial Analyses of Filter No. 20.— Continued.

Collected.			Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.		Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January	10	2.00 p. m.	191	3.2	120	6.6	3.48	679	....	180
"	10	4.00 p. m.	191	3.2	120	7.2	5 48	1,062	....	160
"	10	6.00 p. m.	191	3.2	120	8.0	7.48	1,447	1	100
"	10	8.00 p. m.	191	3.2	120	9.1	9.48	1,830	1	80
"	10	10.00 p. m.	191	3.2	120	10.0	11.48	2,214	1	90
"	10	10.35 p. m.	192	3.2	120	5.0	.08	16	2	375
"	10	10.45 p. m.	192	3.2	120	5.1	.25	48	1	275
"	10	11.00 p. m.	192	3.2	120	5.2	.50	96	1	160
"	11	1.00 a. m.	192	3.2	120	6.9	2.50	480	1	140
"	11	3.00 a. m.	192	3.2	120	7.3	4.50	864	1	80
"	11	5.00 a. m.	192	3.2	120	7.8	6.50	1,248	1	170
"	11	7.00 a. m.	192	3.2	120	8.1	8.50	1,630	1	110
"	11	9.00 a. m.	192	3.2	120	9.2	10.50	2,012	1	200
"	11	10.00 a. m.	192	3.2	120	10.0	11.50	2,204	1	75
"	11	10.40 a. m.	193	3.2	120	5.2	.08	16	1	550
"	11	10.50 a. m.	193	3.2	120	5.3	.25	48	1	300
"	11	11.05 a. m.	193	3.2	120	5.5	.50	96	1	120
"	11	1.00 p. m.	193	3.2	120	5.9	2.42	474	1	120
"	11	3.00 p. m.	193	3.2	120	6.2	4 42	864	1	85
"	11	5.00 p. m.	193	3.2	120	7.1	6.42	1,248	1	28
"	11	7.00 p. m.	193	3.2	120	8.5	8.42	1,633	1	55
"	11	9.00 p. m.	193	3.2	120	9.6	10.42	2,016	1	95
"	12	9.38 p. m.	194	3.2	120	5.0	.08	16	1	325
"	12	9 48 p. m.	194	3.2	120	5.1	.25	48	2	375
"	12	10.03 p. m.	194	3.2	120	5.1	.50	96	2	600
"	12	12.00 p. m.	194	3.2	120	7.0	2.45	476	1	65
"	13	2.00 a. m.	194	3.2	120	8.0	4.45	860	1	28
"	13	4 00 a. m.	194	3 2	120	9.6	6.45	1,241	1	25
"	13	4.43 a. m.	195	3.2	120	5.2	.08	16	4	425
"	13	4.53 a. m.	195	3.2	120	5.3	.25	48	1	110
"	13	5.08 a. m.	195	3.2	120	5.4	.50	96	1	37
"	13	7.00 a. m.	195	3.2	120	6.0	2.37	459	1	18
"	13	9.00 a. m.	195	3.2	120	7.6	4.37	846	1	22
"	13	11.00 a. m.	195	3.2	120	9.1	6.37	1,227	1	8
"	13	12.30 p. m.	195	3.2	120	10.0	7.87	1,513	1	10
"	13	1.05 p. m.	196	3.2	120	5.3	.08	16	1	100
"	13	1.15 p. m.	196	3.2	120	5.3	.25	48	1	85
"	13	1.30 p. m.	196	3.2	120	5.4	.50	96	1	55
"	13	3.00 p. m.	196	3.2	120	5.6	2.00	385	1	28
"	13	5.00 p. m.	196	3.2	120	6.0	4.00	769	1	29
"	13	7.00 p. m.	196	3.2	120	6.6	6.00	1,153	1	39
"	13	9.00 p. m.	196	3.2	120	8.2	8.00	1,537	1	4
"	13	11.00 p. m.	196	3.2	120	8.6	10.00	1,921	1	4
"	14	12.10 a. m.	196	3.1	116	10.0	11.17	2,154	1	13
"	14	12.55 a. m.	197	3.2	120	5.1	.08	16	1	110
"	14	1.05 a. m.	197	3.2	120	5.1	.25	48	1	41
"	14	1.20 a. m.	197	3.2	120	5.2	.50	96	1	30
"	14	3.00 a. m.	197	3.2	120	5.6	2.17	417	1	14
"	14	5.00 a. m.	197	3.2	120	6.4	4.17	808	1	17
"	14	7.00 a. m.	197	3.2	120	7.1	6.17	1,198	1	23
"	14	9.00 a. m.	197	3.2	120	8.3	8.17	1,581	1	28
"	14	11.00 a. m.	197	3.2	120	9.4	10.17	1,965	1	14
"	14	12.30 p. m.	197	3.2	120	10.0	11.67	2,252	2	110
"	14	1.05 p. m.	198	3.2	120	5.0	.08	16	1	200
"	14	1.15 p. m.	198	3.2	120	5.0	.25	48	1	39
"	14	1.30 p. m.	198	3.2	120	5.1	.50	96	1	65
"	14	3.00 p. m.	198	3.2	120	5.5	2.00	386	1	44
"	14	5.00 p. m.	198	3.2	120	5 9	4.00	770	1	10
"	14	7.00 p. m.	198	3.2	120	6 5	6 00	1,154	1	16
"	14	9.00 p. m.	198	3.2	120	8.0	8.00	1,538	1	8
"	14	11.00 p. m.	198	3.2	120	8.6	10.00	1,920	1	18
"	15	12.15 a. m.	198	3.1	116	10.0	11.25	2,156	1	20

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January 15	12.55 a. m.	199	3.2	120	5.0	.08	16	1	100
" 15	1 05 a. m.	199	3.2	120	5.2	.25	48	1	65
" 15	1.20 a. m.	199	3.2	120	5.3	.50	96	1	65
" 15	3.00 a. m.	199	3.2	120	5.9	2.17	423	1	28
" 15	5.00 a. m.	199	3.2	120	6.5	4.17	810	1	11
" 15	7.00 a. m.	199	3.2	120	7.1	6.17	1,199	1	20
" 15	9.00 a. m.	199	3.2	120	7.9	8.17	1,581	1	30
" 15	11.00 a. m.	199	3.2	120	9.3	10.17	1,964	1	23
" 15	12.30 p. m.	199	3.3	120	10.0	11.67	2,250	1	36
" 15	1.05 p. m.	200	3.2	120	5.0	.08	16	1	85
" 15	1.15 p. m.	200	3.2	120	5.0	.25	48	1	93
" 15	1.30 p. m.	200	3.2	120	5.1	.50	96	1	65
" 15	3.00 p. m.	200	3.2	120	5.5	2 00	385	1	50
" 15	5.00 p. m.	200	3.2	120	5.5	4.00	769	1	31
" 15	7.00 p. m.	200	3.2	120	6.1	6.00	1,153	1	75
" 15	9.00 p. m.	200	3.2	120	8.3	8.00	1,535	1	47
" 15	11.00 p. m.	200	3.2	120	9.1	10.00	1,917	1	23
" 16	12.10 a. m.	200	3.2	120	10.0	11.17	2,139	1	27
" 16	12.50 a. m.	201	3.2	120	5.1	.08	16	1	210
" 16	1.60 a. m.	201	3.2	120	5.2	.25	48	1	110
" 16	1.15 a. m.	201	3.2	120	5.2	.50	96	1	70
" 16	3.00 a. m.	201	3.2	120	5.9	2.25	445	1	25
" 16	5.00 a. m.	201	3.2	120	6.2	4.25	835	1	11
" 16	7.00 a. m.	201	3.2	120	7.0	6.25	1,217	1	18
" 16	9.00 a. m.	201	3.2	120	8.7	8.25	1,601	1	20
" 16	11.00 a. m.	201	3.2	120	9.7	10.25	1,985	1	18
" 16	12.00 m.	201	3.2	120	10.0	11.25	2,177	1	12
" 16	12.35 p. m.	202	3.2	120	4.9	.08	16	1	75
" 16	12.45 p. m.	202	3.2	120	4 9	.25	48	1	70
" 16	1.00 p. m.	202	3.2	120	5.0	.50	96	1	42
" 16	3.00 p. m.	202	3.2	120	5.8	2.52	483	1	32
" 16	5.00 p. m.	202	3.2	120	5.9	4.52	867	1	27
" 16	7.00 p. m.	202	3.2	120	7.8	6.52	1,251	1	30
" 16	9.00 p. m.	202	3.2	120	8.5	8.52	1,635	1	30
" 16	11.00 p. m.	202	3.2	120	9.2	10.52	2,019	1	20
" 17	12.10 a. m.	202	3.2	120	10.0	11.69	2,241	2	26
" 17	12.50 a. m.	203	3.2	120	4.9	.08	16	2	170
" 17	1.00 a. m.	203	3.2	120	5.1	.25	48	1	85
" 17	1.15 a. m.	203	3.2	120	5.1	.50	96	1	31
" 17	3.00 a. m.	203	3.2	120	5.7	2.25	440	1	29
" 17	5.00 a. m.	203	3.2	120	6.2	4.25	826	1	15
" 17	7.00 a. m.	203	3.2	120	7.2	6.25	1,309	1	30
" 17	9.00 a. m.	203	3.2	120	8.3	8.25	1,691	1	50
" 17	11.00 a. m.	203	3.2	120	10.0	10.25	1,973	1	43
" 17	11.35 a. m.	204	3.2	120	4.9	.08	16	1	75
" 17	11.45 a. m.	204	3.2	120	4.9	.25	48	2	95
" 17	12.00 m.	204	3.2	120	5.0	.50	96	1	90
" 17	2.00 p. m.	204	3.2	120	5.9	2.53	479	2	110
" 17	4.00 p. m.	204	3.2	120	6.8	4.53	860	2	102
" 17	6.00 p. m.	204	3.2	120	9.4	6.53	1,244	1	190
" 17	7.41 p. m.	205	3.2	120	5.0	.08	16	1	550
" 17	7.51 p. m.	205	3.2	120	5.1	.25	48	2	210
" 17	8.06 p. m.	205	3.2	120	5.3	.50	96	2	200
" 17	10.00 p. m.	205	3.2	120	6.1	2.40	457	2	350
" 17	12.00 p. m.	205	3.2	120	7.5	4.40	841	1	550
" 18	2.00 a. m.	205	3.2	120	8.7	6.40	1,227	1	500
" 18	4.00 a. m.	205	3.2	120	10.0	8.40	1,611	2	575
" 18	4.40 a. m.	206	3.2	120	5.0	.08	16	2	550
" 18	4.50 a. m.	206	3.2	120	5.0	.25	48	1	280
" 18	5.05 a. m.	206	3.2	120	5.1	.50	96	1	1,100
" 18	7.00 a. m	206	3.2	120	6.4	2.42	469	2	1,000
" 18	9.00 a. m.	206	3.2	120	7.0	4.42	857	1	1,100

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.			Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.		Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January	18	11.00 a. m.	206	3.2	120	8.0	6.42	1,241	1	140
"	18	1.00 p. m.	206	3.2	120	8.7	8.42	1,626	1	130
"	18	2.30 p. m.	206	3.2	120	10.0	9.92	1,910	2	120
"	18	3.05 p. m.	207	3.2	120	5.0	.08	16	1	275
"	18	3.15 p. m.	207	3.2	120	5.1	.25	48	1	250
"	18	3.30 p. m.	207	3.2	120	5.1	.50	96	1	250
"	18	5.00 p. m.	207	3.2	120	5.2	2.00	384	1	230
"	18	7.00 p. m.	207	3.2	120	6.9	4.00	778	1	220
"	18	9.00 p. m.	207	3.2	120	7.3	6.10	1,162	1	180
"	18	11.00 p. m.	207	3.2	120	8.2	8.00	1,556	2	250
"	19	1.00 a. m.	207	3.2	120	10.0	10.00	1,941	2	450
"	19	1.40 a. m.	208	3.2	120	5.0	.08	16	2	600
"	19	1.50 a. m.	208	3.2	120	5.1	.25	48	1	400
"	19	2.05 a. m.	208	3.2	120	5.3	.50	96	2	825
"	19	4.00 a. m.	208	3.2	120	5.9	2.42	469	2	190
"	19	6 00 a. m.	208	3.2	120	6.5	4.42	857	1	300
"	19	8.00 a. m.	208	3.2	120	8.1	6.42	1,244	1	700
"	19	10.00 a. m.	208	3.2	120	9.3	8.42	1,625	2	900
"	19	11.30 a. m.	208	3.2	120	10.0	9.92	1,914	2	850
"	19	12 05 p. m.	209	3.2	120	5.0	.08	16	2	650
"	19	12.15 p. m.	209	3.2	120	5.0	.25	48	1	600
"	19	12.30 p. m.	209	3.2	120	5.3	.50	96	2	500
"	19	2.00 p. m.	209	3.2	120	5.3	2.00	384	2	500
"	19	4.00 p. m.	210	3.2	120	4.9	.53	96	1	200
"	19	6.00 p. m.	210	3.2	120	5.6	2.53	480	1	80
"	19	8.00 p. m.	210	3.2	120	6.8	4.53	864	1	85
"	19	10.00 p. m.	210	3.2	120	7.4	6.53	1,248	1	275
"	19	12 00 p. m.	210	3.2	120	8.4	8.53	1,632	1	160
"	20	2.00 a. m.	210	3 2	120	9.5	10.53	2,018	1	170
"	20	3.00 a. m.	210	3.2	120	10.0	11.53	2,212	1	250
"	20	3.40 a. m.	211	3.2	120	5.0	.08	16	2	475
"	20	3.50 a. m.	211	3.2	120	5.1	.25	48	2	160
"	20	4.05 a. m	211	3.2	120	5.2	.50	96	1	37
"	20	6.00 a. m.	211	3.2	120	6.2	2.42	464	1	110
"	20	8.00 a. m.	211	3.2	120	7.2	4.42	852	1	75
"	20	10.00 a. m.	211	3.2	120	7.5	6.42	1,236	2	70
"	20	12.00 m.	211	3.2	120	8.0	8.42	1,621	1	100
"	20	2 00 p. m.	211	3.2	120	10.0	10.42	2,003	1	275
"	20	2.35 p. m.	212	3.2	120	5.1	.08	16	1	250
"	20	2.45 p. m.	212	3.2	120	5.2	.25	48	1	65
"	20	3.00 p. m.	212	3.2	120	5 3	.50	96	2	40
"	20	5.00 p. m.	212	3.2	120	6.1	2.52	480	2	22
"	20	7.00 p. m.	212	3.2	120	6.5	4.52	864	1	21
"	20	9.00 p. m.	212	3.2	120	7.4	6.52	1,248	1	35
"	20	11.00 p. m.	212	3.2	120	8.7	8.82	1,632	1	55
"	21	1.00 a. m.	212	3.2	120	10.0	10.52	2,017	1	180
"	21	1.40 a. m.	213	3.2	120	5.0	.08	16	1	325
"	21	1.50 a. m.	213	3.2	120	5.1	.25	48	2	65
"	21	2.05 a. m.	213	3.2	120	5.3	.50	96	2	70
"	21	4.00 a. m.	213	3.2	120	6.2	2.42	470	1	55
"	21	6.00 a. m.	213	3.2	120	6.8	4.42	855	1	75
"	21	8.00 a. m.	213	3.2	120	8.0	6.42	1,240	2	80
"	21	10.00 a. m.	213	3.2	120	8.5	8.42	1,623	1	90
"	21	12.00 m.	213	3.2	120	9.4	10.42	2,004	1	180
"	21	1.00 p. m.	213	3.2	120	10 0	11.42	2,195	1	250
"	21	1.35 p. m.	214	3.2	120	4.9	.08	16	1	170
"	21	1.45 p. m.	214	3.2	120	5.0	.25	48	1	40
"	21	2.00 p. m.	214	3.2	120	5.3	.50	96	1	26
"	21	4.00 p. m.	214	3.2	120	5.7	2.42	481	1	60
"	21	6.00 p. m.	214	3.2	120	6.8	4.42	865	1	20
"	21	8.00 p. m.	214	3.2	120	7.8	6.42	1,349	1	39
"	21	10.00 p. m.	214	3.2	120	8.4	8.42	1,633	1	22

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.			Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.		Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January	21	12.00 p. m.	214	3.2	120	10.0	10.42	2,019	1	95
"	22	2.00 a. m.	214	3.2	120	10.3	12.42	2,402	1	250
"	22	3.00 a. m.	214	3.2	120	11.0	13.42	2,580	1	325
"	22	3.44 a. m.	215	3.2	120	5.1	.08	16	1	120
"	22	3.54 a. m.	215	3.2	120	5.2	.25	48	1	100
"	22	4.09 a. m.	215	3.2	120	5.4	.50	96	1	65
"	22	6.00 a. m.	215	3.2	120	5.9	2.35	462	1	50
"	22	8.00 a. m.	215	3.2	120	6.3	4.35	846	1	22
"	22	10.00 a. m.	215	3.2	120	7.6	6.35	1,230	1	49
"	22	12 00 m.	215	3.2	120	8.5	10.35	1,613	1	110
"	22	2.00 p. m.	215	3.2	120	10.2	12.35	1,995	1	150
"	22	4.22 p. m.	216	3.2	120	5.2	.08	16	2	500
"	22	4.32 p. m.	216	3.2	120	5.2	.25	48	2	1,000
"	22	4.47 p. m.	216	3.2	120	5.3	.50	96	1	275
"	22	7.00 p. m.	216	3.2	120	7.3	2.72	524	1	90
"	22	9.00 p. m.	216	3.2	120	8.1	4.72	908	1	37
"	22	11.00 p. m.	216	3.2	120	10.0	6.72	1,286	1	33
"	23	3.40 a. m.	217	3.2	120	5.1	.08	16	2	240
"	23	3.50 a. m.	217	3.2	120	5.2	.25	48	1	150
"	23	4.05 a. m.	217	3.2	120	5.9	.50	96	1	110
"	23	6.00 a. m.	217	3.2	120	6.6	2.42	473	1	26
"	23	8.00 a. m.	217	3.2	120	7.1	4.42	862	1	45
"	23	10.00 a. m.	217	3.2	120	7.6	6.42	1,244	2	41
"	23	12.00 m.	217	3.2	120	9.6	8.42	1,625	1	85
"	23	1.30 p. m.	217	3.2	120	10.0	9.92	1,909	1	190
"	23	2.05 p. m.	218	3.2	120	5.0	.08	16	1	275
"	23	2.15 p. m.	218	3.2	120	5.1	.25	48	1	47
"	23	2.30 p. m.	218	3.2	120	5.2	.50	96	1	44
"	23	4.00 p. m.	218	3.2	120	5.6	2.03	384	1	55
"	23	6.00 p. m.	218	3.2	120	7.3	4.03	768	1	25
"	23	8.00 p. m.	218	3.2	120	8.0	6.03	1,152	1	30
"	23	10.00 p. m.	218	3.2	120	8.6	8.03	1,536	1	20
"	23	12.00 p. m.	218	3.2	120	10.0	10.03	1,920	1	39
"	21	12.42 a. m.	219	3.2	120	5.1	.08	16	1	120
"	24	12.52 a. m.	219	3.2	120	5.2	.25	48	1	49
"	24	1.07 a. m.	219	3.2	120	5.3	.50	96	1	45
"	24	3.00 a. m.	219	3.2	120	5.8	2.38	465	1	47
"	21	5.00 a. m.	219	3.2	120	6.7	4.38	851	1	32
"	24	7 00 a. m.	219	3.2	120	7.6	6.38	1,240	1	29
"	24	9.00 a. m.	219	3.2	120	8.4	8.38	1,624	1	28
"	24	10.58 a. m.	220	4.1	153	5.3	.08	21	1	19
"	24	11.05 a. m.	220	4.1	153	5.4	.25	61	1	33
"	24	11.10 a. m.	220	4.1	153	5.7	.50	123	1	15
"	24	11.15 a. m.	220	3.2	120	....	.....	....	1	4
"	24	11.20 a. m.	220	3.2	120	....	.....	....	1	11
"	24	11.25 a. m.	220	3.2	120	....	.....	....	1	17
"	24	11 30 a. m.	220	2.4	90	....	.....	....	2	7
"	24	11.35 a. m.	220	2.4	90	....	.....	....	2	12
"	24	11.40 a. m.	220	2.4	90	....	.....	....	1	13
"	24	11.45 a. m.	220	3.2	120	....	.....	....	2	7
"	24	11.50 a. m.	220	3.2	120	....	.....	....	1	17
"	24	11.55 a. m.	220	3.2	120	....	.....	....	1	26
"	24	12.00 m.	220	4.1	153	6.5	1.12	213	1	33
"	24	12.05 p. m.	220	4.1	153	....	.....	....	2	23
"	24	12 10 p. m.	220	4.1	153	....	.....	....	1	18
"	24	12.15 p. m.	220	3.2	120	....	.....	....	1	24
"	24	12.20 p. m.	220	3.2	120	....	.....	....	1	20
"	24	12.25 p. m.	220	3.2	120	....	.....	....	1	17
"	24	12.30 p. m.	220	2.4	90	....	.....	....	1	20
"	24	12.35 p. m.	220	2.4	90	....	.....	....	1	23
"	24	12.40 p. m.	220	2.4	90	....	.....	....	1	9
"	24	12.45 p. m.	220	3.2	120	....	.....	....	1	12

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.		Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.	Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January 24	12.50 p. m.	220	3.2	120	....	.....	....	1	13
" 24	12.55 p. m.	220	3.2	120	....	.....	....	1	19
" 24	1.00 p. m.	220	4.1	153	6.5	2.12	404	1	24
" 24	1.05 p. m.	220	4.1	153	....	.....	....	1	35
" 24	1.10 p. m.	220	4.1	153	....	.....	....	1	32
" 24	1.15 p. m.	220	3.2	120	....	.....	....	1	10
" 24	1.20 p. m.	220	3.2	120	....	.....	....	1	13
" 24	1.25 p. m.	220	3.2	120	....	.....	....	1	19
" 24	1.30 p. m.	220	2.4	90	....	.....	....	1	18
" 24	1.35 p. m.	220	2.4	90	....	.....	....	1	15
" 24	1.40 p. m.	220	2.4	90	....	.....	....	1	16
" 24	1.45 p. m.	220	3.2	120	....	.....	....	1	30
" 24	1.50 p. m.	220	3.2	120	....	.....	....	1	19
" 24	1.55 p. m.	220	3.2	120	....	.....	....	1	34
" 24	2.00 p. m.	220	4.1	153	7.8	3.12	597	1	36
" 24	2.05 p. m.	220	4.1	153	....	.....	....	1	41
" 24	2.10 p. m.	220	4.1	153	....	.....	....	1	35
" 24	2.15 p. m.	220	3.2	120	....	.....	....	1	19
" 24	2.20 p. m.	220	3.2	120	....	.....	....	1	20
" 24	2.25 p. m.	220	3.2	120	....	.....	....	1	18
" 24	2.30 p. m.	220	2.4	90	....	.....	....	1	20
" 24	2.35 p. m.	220	2.4	90	....	.....	....	1	24
" 24	2.40 p. m.	220	2.4	90	....	.....	....	1	14
" 24	2.45 p. m.	220	3.2	120	....	.....	....	1	18
" 24	2.50 p. m.	220	3.2	120	....	.....	....	1	11
" 24	2.55 p. m.	220	3.2	120	....	.....	....	1	16
" 24	3.00 p. m.	220	4.1	153	8.4	4 12	895	1	36
" 24	3.05 p. m.	220	4.1	153	....	.....	....	1	26
" 24	3.10 p. m.	220	4.1	153	....	.....	....	1	43
" 24	3.15 p. m.	220	3.2	120	....	.....	....	1	17
" 24	3.20 p. m.	220	3.2	120	....	.....	....	1	23
" 24	3.25 p. m.	220	3.2	120	....	.....	....	1	27
" 24	3.30 p. m.	220	2.4	90	....	.....	....	1	25
" 24	3.35 p. m.	220	2.4	90	....	.....	....	1	15
" 24	3.40 p. m.	220	2.4	90	....	.....	....	1	13
" 24	3.45 p. m.	220	3.2	120	....	.....	....	1	47
" 24	3.50 p. m.	220	3.2	120	....	.....	....	1	26
" 24	3.55 p. m.	220	3.2	120	....	.....	....	1	27
" 24	4.00 p. m.	220	4.1	153	8.6	5 12	992	2	38
" 24	4.05 p. m.	220	4.1	153	....	.....	....	1	27
" 24	4.10 p. m.	220	4.1	153	....	.....	....	1	43
" 24	4.15 p. m.	220	3.2	120	....	.....	....	1	23
" 24	4 20 p. m.	220	3.2	120	....	.....	....	1	15
" 24	4 25 p. m.	220	3.2	120	....	.....	....	1	25
" 24	4.30 p. m.	220	2.4	90	....	.....	....	1	29
" 24	4.35 p. m.	220	2.4	90	....	.....	....	1	40
" 24	4 40 p. m.	220	2.4	90	....	.....	....	1	11
" 24	4.45 p. m.	220	4.1	153	....	.....	....	1	7
" 24	4.50 p. m.	220	4.1	153	....	.....	....	1	18
" 24	4.55 p. m.	220	4 1	153	....	.....	....	1	19
" 24	5.00 p. m.	220	3.2	120	10.0	6.12	1,220	1	25
" 24	5.55 p. m.	221	3.2	120	5.1	.08	16	1	230
" 24	6.05 p. m.	221	3.2	120	5.2	.25	48	1	90
" 24	6.20 p. m.	221	3.2	120	5.4	.50	96	1	50
" 24	8.00 p. m.	221	3.2	120	6.5	2.17	418	1	33
" 24	10.00 p. m.	221	3.2	120	7.3	4.17	802	1	26
" 24	12.00 p. m.	221	3.2	120	8.5	6.17	1,287	1	39
" 25	1.15 a. m.	221	3.2	120	10.0	7 42	1,427	1	25
" 25	1.52 a. m.	222	3.2	120	5.0	.08	16	1	240
" 25	2.02 a. m.	222	3.2	120	5.1	.25	48	1	70
" 25	2.17 a. m.	222	3.2	120	5.2	.50	96	1	55
" 25	4.00 a. m.	222	3.2	120	6.3	2.22	429	1	8

Results of Bacterial Analyses of Filter No. 20.—Continued.

Collected.			Number of Run.	Rate of Filtration.		Loss of Head.	Period of Service since Last Washing.	Filtered Water since Last Washing.	Degree of Clearness.	Bacteria per Cubic Centimeter.
Date—1899.		Hour.		Cubic Feet per Minute.	Million Gallons per Acre per 24 Hours.	Feet.	Hours.	Cubic Feet.		
January	25.....	6.00 a. m.	222	3.2	120	7.0	4.22	818	1	14
"	25.....	8.00 a. m.	222	3.2	120	7.4	6.22	1,203	1	43
"	25.....	10.00 a. m.	222	3.2	120	8.2	8.22	1,567	1	17
"	25.....	12.00 m.	222	3.2	120	9.6	10.22	1,969	1	20
"	25.....	1.00 p. m.	222	3.2	120	10.0	11.22	2,160	1	34

PART II.

Report upon the Results obtained from the Official Test of the System of Purification of the Ohio Sanitary Engineering Company,

MARCH 13 TO APRIL 25, 1899.

CINCINNATI, O., June 21, 1899.

BOARD OF TRUSTEES,

"COMMISSIONERS OF WATERWORKS,"

CINCINNATI, OHIO:

GENTLEMEN, — I submit herewith the full report of Mr. G. W. Fuller on the results of the test made at the Eden Park Experimental Plant of the system of water purification of the Ohio Sanitary Engineering Company. The process as tested in its final development was different from that experimented upon at Louisville by the same Company, the principal points of differentiation being the introduction of settling tanks whereby a period of twelve hours was given for the coagulating effect of the lime water on the suspended matter in the river water, and the use of carbonic acid gas to neutralize the excess of free lime remaining in the water after the first filtration. As will be seen by the detailed report of Mr. Fuller, the suspended matter and the bacteria were removed almost completely by the use of lime, but the neutralization of the free lime by carbonic acid was not accomplished in a satisfactory manner.

Respectfully,

G. BOUSCAREN,

Chief Engineer.

MR. G. BOUSCAREN, *Chief Engineer*,
Board of Trustees, "*Commissioners of Waterworks*,"
Cincinnati, O.:

DEAR SIR,—Herewith is presented the full report upon the results of the official test of the system of purification of the Ohio Sanitary Engineering Company.

ORIGIN AND CONDITIONS OF THE TEST.

The official test by the city of Cincinnati of the system of purification in question had its origin in the following communication, which was presented to the Board of Trustees at their regular meeting on November 29, 1898:

COLUMBUS, O., November 29, 1898.

To the Honorable Board of Water Commissioners,
Cincinnati, O.:

GENTLEMEN,—We beg to state that we are prepared to supply a system to clarify and purify the water supply of Cincinnati.

In explanation of our process: We clarify and purify the water without the use of sedimentation basins, and without the use of *sulphate of alumina* or of *sulphate of iron*, thereby obtaining a high degree of purity in the final effluent with great economy.

We are prepared to demonstrate these facts to you, at your convenience, with a plant which is at present in operation at

the Louisville Water Company's Pumping Station at Louisville, Ky., where you can investigate the matter for yourselves by visiting the said plant, which we presume would be more satisfactory to you in comparison with any data which we might supply at this writing. After having viewed and investigated our process at Louisville, and if it should recommend itself to you, we would be pleased then to enter into a contract to supply a complete plant of our system in accordance with certain drawings and specifications, which would show the plant complete in every respect, ready to be connected up with your waterworks system; and we would also supply you with a good and sufficient bond to guarantee the workmanship and faithful performance of such contract.

By adopting our system you can save a very large sum in the cost of construction of the works, and what is of much greater importance to you, viz., the saving which can be made in the non-use of chemicals in our process; also the large saving which we make in the quantity of water used by us in the washing out of the filters. Those savings are in addition to a saving which we also make in labor in comparison with sand filtration.

Our claims are—

First—The cheapness of the installation of the works.

Second—The small area of ground required for the works.

Third—The simplicity of our system, and the ease with which it can be operated.

Fourth—The large saving made in the *non-use of sulphate of alumina* or *sulphate of iron.*

Fifth—The large saving made in the comparatively small quantity of water we require to wash out our filters.

Sixth—The saving which we make in the cost of labor to operate the work.

Seventh—The high degree of purity obtained.

Eighth—No royalties charged.

Respectfully,

OHIO SANITARY ENGINEERING CO.
Per HORACE W. AVERY, *President.*
J. P. BLISS, *Secretary.*

At a meeting of the board held on January 17, 1899, when the experiments conducted by the city at the purification plant near the Eden Park reservoir were practically finished, the

Board of Trustees, "Commissioners of Waterworks," adopted the following resolution:

"*First*—That all experimental work as now conducted at the Eden Park Station be discontinued on and after February 1, 1899.

"*Second*—That the Ohio Sanitary Engineering Company shall after February 1, 1899, be given possession of such portions of the Eden Park plant as may be necessary to make a demonstration of their filtering process, said company to have a right to make such alterations of said plant, under the supervision of this board, as they may deem necessary, and to maintain said plant during the time they are making their demonstration; provided, however, that the entire cost of such alterations and maintenance of said plant, and for the machinery which they may require for making said demonstration, shall be paid by said company, and that no part of it shall be borne by this board.

"*Third*— That after said alterations have been made by said company they shall be permitted to demonstrate their system of filtration for a period of thirty days, said demonstration to be under the supervision of G. W. Fuller and the direction of the representatives of said company, and that the expense of such supervision shall be borne by this board; and that it shall be the duty of Mr. Fuller to make analyses of the crude water and of the final effluent, as well as the cost of obtaining the same per million gallons, and report the same to this board.

"When said demonstration has been completed by said company they shall be permitted, at their own expense, to take out all the appliances, tools, and machinery that they may have put in said plant at their own expense."

Upon the completion of the operations conducted by the city, on January, 25, 1899, the plant was drained and placed in as good condition as practicable; and after taking an inventory of the equipment the entire plant, except the laboratory and office building, was turned over to the Ohio Sanitary Engineering Company.

In order that there should be no misunderstanding as to the conditions under which the test was to be conducted, the

Chief Engineer issued to the writer the following instructions, which were approved and indorsed by the Board of Trustees on January 27, 1899:

"*First*—Operations are to be continuous, day and night.

"*Second*—Should interruption occur, you will request in writing from the company's representative the cause thereof, and the probable duration of such interruption.

"*Third*—Yourself and assistants are to have free access at all times to all parts of the plant for the purpose of examination, measurements, and procuring any information you may deem necessary or desirable for a complete description of the appliances and the method employed.

"*Fourth*—You are to procure from the company all explanations and facts that you may deem necessary to supplement your own observations, including a statement as to the kind and quantity of chemicals used.

"*Fifth*—The work of yourself and assistants is to be confined to the supervision of the work done by the company, the measurement of the quantities of water treated and used for washing or other purposes connected with the process, the analysis of the water before treatment and after each of the several treatments constituting the complete process of purification, the keeping of complete records of results, and the collection of all facts necessary for a full description of the appliances used, the method of operation employed, and the cost of purification by said process. All other work is to be done by the company, including the alterations to be made in the present plant, the maintenance of the plant in good condition, the furnishing and preparation of materials and supplies (excepting laboratory supplies), and all other things required to operate the plant.

"*Sixth*—Your reports are to be made to the Board of Trustees and to the Chief Engineer only, the company to secure transcripts of analytical evidence from these reports, should they so desire."

Period of Investigation and Distribution of Time.

The entire month of February, 1899, was occupied by the Ohio Sanitary Engineering Company in making modifications and additions to the purification plant. During the first twelve

days in March the plant was in preliminary operation from time to time, in order that the attendants of the company should become familiar with their work; but severe cold weather interfered with progress considerably. On March 13, 1899, the plant was in readiness for the official test, and provided with necessary meters, gages, sample-taps, etc.

The official tests for thirty days covered the period from March 13 to April 12, 1899. On April 11 the Ohio Sanitary Engineering Company requested that the official tests be continued in order that more definite information might be obtained; and the board decided that the official tests should cease on and after April 25, 1899. After the latter date the time was devoted to the preparation of this report, and while this system of purification was afterwards in unofficial operation on a number of occasions, it received attention from the city only on May 2, in connection with a few special points.

Force Employed.

The force employed in conducting this official test included seven men besides the writer and a janitor, as follows:

Mr. Joseph W. Ellms.....Assistant Chemist.
Mr. Alex. N. Miller .....Assistant.
Mr. Leon Tedesche ..... "
Mr. Wm. H. Getz ..... "
Mr. William Gray .....Inspector.
Mr. Robert Hug ..... "
Mr. Isaac Saint..... "

Messrs. Miller, Tedesche, and Getz were employed on the engineering, bacterial, and chemical work, respectively. To the entire force the writer wishes to acknowledge the satisfactory performance of the allotted work.

Cost of the Test.

The total cost to the city of this test from February 1 to May 24, 1899, was $3,327.63, distributed as follows:

Laboratory apparatus and supplies	8 95
Office supplies	9 60
General supplies, including coal, gas, ice, etc.	112 03
Salaries	3,165 00
Incidentals	32 05
Total	$3,327 63

Adding this sum to the amount spent previous to February 1, 1899, $38,260.29, makes $41,587.92 as the total cost to the city of Cincinnati of preliminary investigations upon the purification of the local water supply, exclusive of the printing of the report.

Brief Outline of Report.

The plan of presentation in this report is substantially the same as was followed in a previous report upon the purification of this water supply, which was made to you on January 31, 1899, and transmitted to the board on February 17, 1899. In many instances in this report references are made to the "previous report," mentioned above.

For convenience this report is divided into six sections, as follows:

SECTION I—Composition of the Ohio River water at Cincinnati during the official test.

SECTION II—Outline of the principles upon which this system of purification is based, with a description of the devices and appliances used therewith.

SECTION III—Description of the operation of this system of purification and its modifications.

SECTION IV—Explanation and tabulation of results accomplished during the official test of this system.

SECTION V—Summary and discussion of the qualitative efficiency of this system.

SECTION VI—Summary of actual data, supplemented by estimates, and discussion of the cost of purification by this system.

SECTION I.

COMPOSITION OF THE OHIO RIVER WATER AT CINCINNATI DURING THE OFFICIAL TEST OF THIS SYSTEM.

The Ohio River water which was treated during this test came from the same intake (Front Street) as was the case during previous tests, and its general characteristics are set forth in Chapter I of the previous report. It only remains in this connection to place on record its composition during this test, and compare the amount of the several constituents with the normal as determined for the year 1898.

From March 1 to April 25, 1899, the total rainfall at Cincinnati was 7.08 inches, or about 20 per cent above the normal for this period. The average stage of the Ohio River at this point during this period was 35.2 feet, or about 7 feet above the normal for this period. The complete data for the stations above Cincinnati are not now available; but, judging from the Weather Bureau maps for six days per week, it is clear that the period of this test was one of somewhat greater rainfall and of greater freshets than is normally the case during this season of the year, and particularly during the entire year.

From January 26 to February 28, 1899, the period of preparation preceding this test, daily determinations were made, as a matter of record, of the amount of suspended matter in the river water, with results as follows.

Table showing the Suspended Matter in Parts per Million in the Ohio River Water at Cincinnati from January 26 to February 28, 1899, with Corresponding Stages of the River in Feet.

Date.	Stage of River.	Suspended Matter.	Date.	Stage of River.	Suspended Matter.
January 26.....	27.9	354	February 12....	26.2	.....
" 27.....	30.6	541	" 13....	22.5	145
" 28.....	29.6	367	" 14....	15.0	147
" 29.....	28.5	.....	" 15....	13.3	102
" 30.....	26.4	202	" 16....	13.9	99
" 31.....	24.4	113	" 17....	12.3	61
February 1.....	22.3	94	" 18....	11.5	84
" 2.....	20.0	122	" 19....	12.6	.....
" 3.....	16.5	95	" 20....	14.9	209
" 4....	17.1	297	" 21....	25.8	336
" 5.....	21.5	.....	" 22....	32.1	621
" 6.....	27.3	542	" 23....	34.6	594
" 7.....	34.5	988	" 24....	35.6	323
" 8.....	37.7	695	" 25....	35.9	300
" 9.....	38.7	418	" 26....	36 2	305
" 10....	37.7	417	" 27....	39.0	553
" 11.....	31.4	206			

Beginning on March 1, 1899, when the system went into preliminary operation, daily samples of river water were collected for bacterial and complete chemical analyses. This plan was continued until the close of the official test, except that, beginning on March 13, portions were collected of the river water at 8 A. M., 4 P. M., and 12 P. M. daily. The samples for chemical analysis were mixed together in equal quantities to give an average sample for the day, while the number of bacteria were determined separately on each occasion, and the average of the results was recorded for the day.

One of the most important features obtained from these analyses was the comparison of the river water treated during the official test (March 13 to April 25) with the normal, as shown by the average for the year 1898. This is shown for the several constituents in the following summaries for the maximum and minimum as well as the normal:

Summary showing a Comparison of the several Constituents in the River Water during the Test and during the Year 1898.

Constituents.	Parts per Million.	
	Average March 13 to April 25, 1899.	Normal for 1898.
Total suspended matter	273.0	230.0
Suspended organic matter (nitrogen as albuminoid ammonia)	0.175	0.200
Total dissolved residue	104.0	120.0
Total carbonaceous organic matter	5.7	4.0
Total nitrogenous organic matter	0.236	0.290
Nitrogen as free ammonia	0.007	0.025
Nitrogen as nitrites	0.002	0.003
Nitrogen as nitrates	0.76	0.60
Chlorine	5.9	10.0
Sulphuric acid	22.0	24.0
Incrusting constituents	29.0	33.0
Alkalinity	40.0	45.0
Dissolved oxygen	9.3	7.2
Carbonic acid	21.0	26.0
Bacteria per cubic centimeter	24,000	20,000

Summary showing a Comparison of Constituents — Concluded.

Constituents.	Maximum. Parts per Million.		Minimum. Parts per Million.	
	March 13 to April 25, 1899.	1898.	March 13 to April 25, 1899.	1898.
Total suspended matter	944.0	2383.0	70.0	24.0
Suspended organic matter (nitrogen as albuminoid ammonia)	0.544	0.753	0.044	0.022
Total dissolved residue	143.0	223.0	68.0	67.0
Total carbonaceous organic matter	14.3	16.8	2.5	1.8
Total nitrogenous organic matter	0.616	0.868	0.092	0.106
Nitrogen as free ammonia	0.022	0.074	0.002	0.008
Nitrogen as nitrites	0.004	0.030	0.000	0.000
Nitrogen as nitrates	0.94	1.34	0.46	0.37
Chlorine	8.0	44.00	14.0	3.0
Sulphuric acid	26.0	46.0	4.0	13.0
Incrusting constituents	52.0	57.0	17.0	11.0
Alkalinity	53.0	70.0	32.0	20.0
Dissolved oxygen	10.2	10.0	8.1	3.4
Carbonic acid	31.0	47.0	10.0	6.0
Bacteria per cubic centimeter	55,000	155,000	5,200	1,000

For a thorough comparative study of the composition of the river water during this period it is necessary to consult the detailed analytical evidence which is tabulated beyond.

An explanation of the methods of analyses and of the significance of the results obtained will be found on pages 19 to 30 of the previous report. With reference to the carbonaceous and nitrogenous organic matter, mentioned in the foregoing summaries, it may be noted that they are represented by the oxygen consumed and nitrogen as albuminoid ammonia, respectively.

Owing to the turbidity of the water, the examinations for algæ and microscopical organisms are unsatisfactory, and were omitted. A number of tests of the river water were made for the presence of fecal bacteria, and the results were positive in about one half of the cases.

Results of the Chemical and Bacterial Analyses of Ohio River Water.

[*Chemical Results Expressed in Parts per Million*]

Collected—1899.	Temperature, Deg. C.	Color.	Oxygen Consumed.	Nitrogen as Albuminoid Ammonia.			Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Sulphuric Acid.	Incrusting Constituents.	Alkalinity.	Residue on Evaporation.			Iron.	Carbonic Acid.	Dissolved Oxygen.	Bacteria per Cubic Centimeter.
				Total.	Suspended.	Dissolved.								Dissolved.	Suspended.	Total.				
March 1	3.0	.08	14.3	.746	.692	.054	.018	.004	1.02	6.0	18	35	32	87	970	1,057	40	....	....	41,000
" 2	4.0	.10	7.8	.492	.382	.110	.014	.003	1.02	6.0	18	30	36	101	466	567	20	26	....	46,700
" 3	5.0	.10	7.3	.336	.264	.072	.020	.002	0.82	5.5	24	27	28	89	391	480	17	15	....	43,200
" 4	5.0	.10	5.9	.340	.256	.084	.022	.004	1.02	5.0	20	16	43	97	365	462	19	18	....	48,100
" 5	4.0	.13	12.6	.750	.658	.092	.026	.003	0.94	6.0	19	29	44	101	777	878	38	17	....	49,000
" 6	6.0	.13	14.7	.574	.504	.070	.022	.001	0.86	5.0	18	23	32	92	990	1,082	40	14	....	40,700
" 7	6.0	.11	13.1	.514	.444	.070	.020	.000	0.86	6.0	17	19	18	68	817	885	44	12	....	37,100
" 8	6.0	.11	10.1	.376	.326	.050	.018	.000	0.92	6.5	20	21	18	75	545	620	25	15	....	38,800
" 9	6.0	.11	8.5	.332	.272	.060	.014	.001	0.88	6.0	20	24	22	68	474	542	26	14	....	34,400
" 10	6.0	.12	8.2	.322	.252	.070	.016	.001	0.94	7.0	22	25	25	77	504	581	27	14	....	28,000
" 11	5.0	.10	7.2	.292	.234	.058	.016	.003	0.92	6.0	23	20	27	97	347	444	22	17	....	35,100
" 12	5.0	.13	7.8	.274	.202	.072	.012	.002	0.90	6.0	23	21	39	93	287	380	18	18	....	29,000
" 13	5.0	.08	6.0	.268	.216	.052	.012	.003	0.86	6.0	23	21	35	105	245	350	11	22	....	25,700
" 14	5.0	.08	5.5	.216	.202	.014	.008	.001	0.90	5.0	22	26	41	95	243	328	13	20	9.1	23,900
" 15	6.0	.06	5.6	.238	.160	.078	.008	.002	0.82	6.0	20	34	39	102	227	329	13	27	....	25,800
" 16	6.0	.06	5.0	.224	.170	.054	.008	.002	0.86	6.0	23	35	42	117	210	327	11	20	....	19,900
" 17	7.0	.08	4.8	.190	.114	.076	.012	.002	0.90	5.0	25	41	41	96	200	295	10	16	....	23,500
" 18	8.0	.08	4.9	.184	.116	.068	.008	.002	0.86	6.0	26	50	47	121	174	295	10	19	....	32,800
" 19	6.0	.10	7.1	.312	.228	.084	.012	.002	0.94	5.0	25	52	53	143	387	530	17	21	....	37,100
" 20	6.0	.10	6.9	.368	.310	.058	.008	.001	0.90	5.0	25	33	48	141	469	610	21	28	8.1	55,000
" 21	7.0	.07	7.1	.314	.264	.050	.006	.001	0.78	6.0	26	42	35	107	410	517	23	20	....	31,400
" 22	8.0	.07	7.4	.314	.268	.046	.006	.001	0.62	6.0	24	48	34	89	461	550	25	21	....	27,400
" 23	8.0	.09	7.2	.374	.310	.064	.006	.001	0.62	5.0	26	25	34	85	438	523	23	22	....	37,400
" 24	7.0	.10	5.9	.264	.196	.068	.004	.002	0.74	6.0	25	26	32	80	277	357	19	22	....	29,500
" 25	8.0	.10	5.0	.240	.176	.064	.004	.002	0.78	6.0	26	25	41	90	235	325	15	22	....	37,700
" 26	7.0	.10	5.7	.266	.192	.074	.022	.002	0.78	6.0	26	26	41	117	225	342	16	23	....	86,300
" 27	7.0	.08	6.4	.260	.188	.072	.011	.002	0.82	6.0	23	27	38	94	213	307	14	21	....	34,000
" 28	6.0	.12	8.4	.166	.388	.078	.012	.001	0.94	6.5	[illegible]	22	40	100	509	609	21	23	....	36,000

| | | |

SECTION II.

Outline of the Principles upon which this System of Purification is based, with a Description of the Devices and Appliances used therewith.

In its simplest terms this system of purification as originally constructed here consisted of four distinct steps, as follows:

1. The application to the river water of a certain quantity of a saturated solution of lime water.

2. The precipitation of the greater part of the suspended matters in the lime-treated water by its upward passage through a tank holding substantially 12 hours flow of water.

3. The filtration of the effluent of the precipitation tank at a rate of 100 million gallons per acre daily, through a sand filter equipped with an agitator and appliances for washing with filtered water pumped into the filter from below.

4. The filtration of the effluent of the sand filter at a rate of 50 million gallons per acre daily, through a polarite filter containing a mixture of sand and polarite, and equipped with agitating and washing appliances similarly to the sand filter.

The normal capacity of this system as tested was 250,000 gallons per 24 hours.

At the outset of this test it was not definitely known just what the effect would be upon the river water of the applied lime water, in the amounts which would be used. Naturally the application of lime water recalls the Clark process of soft-

ening water, patented in England in 1841, and which is known to serve, in a measure, as a clarifying and purifying process. In the Clark process the applied lime water combines with the carbonic acid in the water to be treated, and forms a precipitation of carbonate of lime (chalk) which is practically insoluble in water free from carbonic acid. This precipitate of carbonate of lime is amorphous or granular, and not gelatinous.

In the system or process of the Ohio Sanitary Engineering Company, a part of the applied lime water combined, of course, with the carbonic acid in the river water. Very early in this work it was learned that, with the grades of river water being treated, the resulting carbonate of lime was totally inadequate to give to the river water a proper preparatory treatment, in order that the water might subsequently be purified with success by rapid subsidence and rapid filtration. It was found necessary to apply an excess of lime water—that is, a quantity greater than would combine with the carbonic acid—in order that the fine clay particles in the water might be suitably aggregated into relatively large masses.

The property which lime possesses of coagulating water containing fine clay particles is a phenomenon which has been known to agricultural chemists for many years, and one which has not been explained in a manner that is universally acceptable. This subject is best reviewed, so far as we know, by Mr. H. W. Wiley, Chief Chemist of the U. S. Department of Agriculture, in his book on the "Principles and Practice of Agricultural Analysis," Vol. I, pages 171 to 183. The only new and practical feature apparently in connection with the application of lime water to coagulate this river water lies in the comparatively small amount of lime required to coagulate the water so thoroughly; but from actual knowledge the his-

tory of the use of lime in the treatment of this general class of river waters is not definitely known.

At first it was thought that the excess of lime acted as a germicide, and in a large measure explained the very low numbers of bacteria in the effluent. Subsequent information showed, however, that the bacterial quality of the effluent was attributable specifically to the coagulation of the water prior to filtration. To effect the coagulation properly it was necessary to apply an adequate excess of lime water, and the amount of this excess corresponded to the amount and character of the matters suspended in the river water.

With a suitable degree of coagulation of the effluent of the precipitation tank, it was found that the effluent of the sand filter was brilliant in appearance, and very low in its contents of bacteria and organic matter. Owing to the comparatively small amount of suspended matter in the water applied to the sand filter, the amount of wash water required was a relatively small percentage of the total effluent.

Under these conditions the amount of work normally for the polarite filter to do was merely nominal; and, as it showed itself to be incapable of correcting the effect of an inadequate application of lime, it was obviously a superfluous part of the system, so far as turbidity, bacteria, and organic matter in the effluent were concerned.

But as it was found that the excess of lime water for the most part appeared in the effluent of the sand filter, and as the excess of lime in the effluent is inadmissible, as is shown more fully in Section V, the process as it stood required that the excess of lime should be removed properly before it could be regarded as a satisfactory one. To accomplish this end carbonic acid was applied to form the insoluble carbonate of lime to be removed by subsidence or filtration.

During the official test carbonic acid gas was applied to the water, for the purpose of eliminating the excess of lime at three different stages in the process at different times, as follows:

1. To the river water before it was treated with lime water and before its entrance to the precipitation tank.

2. To the effluent of the precipitation tank as it entered the sand filter.

3. To the effluent of the sand filter and before its entrance to the polarite filter.

The application of carbonic acid to the river water for a short time reduced the excess of lime in the effluent. But, as was anticipated, it caused a failure in the coagulation of the water, and consequently in the character of the effluent from every standpoint except the excess of lime. The explanation of this experience is made plain by the foregoing description of the manner in which the coagulation is accomplished.

When the carbonic acid was applied to the coagulated water as it entered the sand filter there were many indications that the acid, in a measure, undid the coagulation of the clay particles, and thereby, in part, unfitted the effluent of the precipitation tank for rapid and successful filtration through the sand filter. This matter is taken up again beyond in connection with the actual data obtained therewith.

The official test closed with the application of the carbonic acid to the water between the sand filter and the polarite filter.

In concluding this brief outline of the principles upon which is based the system of purification of the Ohio Sanitary Engineering Company, it will be seen that it is to be classified as similar to the American System as described in the previous report; that is to say, it consists in precipitation

of the river water (previously coagulated), and the subsequent filtration at a rapid rate of the partially clarified and thoroughly coagulated water. It differs chiefly in that it requires a double application of chemicals to the water, and apparently a double filtration of the water.

DESCRIPTION OF THE DEVICES AND APPLIANCES USED IN THE SYSTEM OF PURIFICATION OF THE OHIO SANITARY ENGINEERING COMPANY.

At the beginning of this description it is necessary to state, as a matter of record, that on a number of occasions during the construction and arrangement of these devices the gentlemen in charge of this system showed considerable opposition towards the representatives of the board when getting the necessary measurements, etc. So far as the writer has been able to learn, this conduct is explained by the position of the Engineering Company in this connection, as follows:

1. These devices were temporary in nature and adapted to the local conditions at this plant with a minimum outlay of time and money, and they did not want to be committed to these types of construction.

2. They are spending considerable money for the purpose of securing patents, and do not want other parties to have records and drawings of their devices.

3. In the event that their devices should be successful they will furnish ample drawings with details in due time; but if they should fail the records will be of no value to the board, and the Engineering Company does not want them to become a matter of detailed record.

As instructed by you in your letter of February 28, 1899, all information obtained in connection with these tests has been treated as confidential.

In the judgment of the writer, the following description of the devices used by the Engineering Company is sufficient for present purposes. These devices may be subdivided into five groups, as follows:

1. Devices for the preparation and the application of lime water.

2. A tank in which the river water was treated with lime water, and subsided on the continuous displacement plan, to precipitate the coarser suspended matters.

3. A sand filter with mechanical washing devices, receiving the effluent of the precipitation tank at a rate of 100 million gallons per acre daily.

4. A polarite filter with mechanical washing devices, receiving the effluent of the sand filter at the rate of 50 million gallons per acre daily.

5. Devices for the application of carbonic acid.

Before giving a somewhat detailed description in turn of each of the devices and appliances reference is made to Chapter II and the accompanying plates of the previous report for descriptions of the experimental purification plant, as it stood prior to its being turned over to the Ohio Sanitary Engineering Company. In describing the devices as modified and employed by this company, assistance is gained from the previous descriptions, and the old devices are designated by the names originally used.

Lime Devices.

Lime-slaking Tank.—On a small platform placed between the steel tanks and the filters was a small wooden tank 2 by 3 by 4 feet, in which the lime was slaked, and at a sufficient elevation to allow the lime to be flushed through an open wooden trough into either solution tank, as desired.

Solution Tanks.— One 8-foot tank (old filter No. 9) and one 6-foot tank (old filter No. 3), both 11.78 feet in diameter, were placed upon suitable foundations adjoining the west side of the filter platform and towards the south end. The open trough leading from the slaking tank connected with the solution tanks at the top. The two tanks had an available capacity of about 5,620 and 4,500 gallons, respectively.

Applied Water.— At the beginning of the official test the lime was slaked and dissolved with filtered water pumped from the effluent of the polarite filter. On March 18, however, a change was made, and thereafter river water under pressure was taken from the inlet pipe for the preparation of the lime water.

Lime-water Pump.— A duplex steam pump, 4.5 by 2.75 by 4 inches, with its suction about 5 inches above the bottom of either solution tank (and with the end of the suction pipe covered with a bag) elevated the lime water through a 2-inch pipe to a point above the mixing gutter at the top of the precipitation tank and near the mouth of the river-water pipe. A meter was placed near the pump on this 2-inch delivery pipe.

Experience soon showed that this pump was too large to be capable of satisfactory regulation when delivering suitable quantities of lime water when the river was in a fairly clear condition, and on March 18 it was replaced by a smaller pump. The second pump was 3.5 by 2 by 3 inches in size.

Precipitation Tank.

The following changes were made in the original tank D (25 feet in diameter and 34 feet high), which was adapted to serve as a precipitation tank.

Inlet.—The original inlet pipe was broken about 4 inches above the ground as it rose to the tank, and a plug was put into the upper portion of the pipe about one foot below the bottom of the tank. A 6-inch extension of the inlet was carried under the tank and up on the side about 2 feet south of the ladder, so as to discharge into a gutter at the top of the tank.

Mixing Gutter.—Around the periphery of the tank at the top a 10-inch by 12-inch gutter was supported on radial beams, having a total length of about 80 feet. The river water and lime water were discharged into this gutter at the end, beginning beneath the mouth of the inlet pipe. The other end terminated at a vertical 12-inch standpipe placed in the center of the tank.

Standpipe.—The 12-inch standpipe conveyed the mixed river water and lime water downward, and extended to within 10 inches of the bottom of the tank. It rested in the bottom of a galvanized can 3 feet high and about 2 feet in diameter, properly supported. At the bottom of the standpipe were four vertical openings 2.5 inches by 9 inches. To cause a uniform movement of the water upward an inverted sheet-iron cone 10.5 feet in diameter at the bottom and attached to the pipe at its top was put in place. The cone was 7 feet high; its bottom was 3.5 feet above the bottom of the tank; and it was perforated with about 432 holes 0.75 inch in diameter, regularly spaced. The bottom of this cone was 9 inches distant from a wooden hopper to facilitate the removal of the sediment.

Wooden Hopper.—A slope of 45 degrees was secured at the bottom of the tank by sheathing laid on suitable supports. At the periphery this slope began 10 feet above the bottom, and it ended on the bottom 10 feet from the wall of the tank. This

hopper deflected the sediment towards the space on the bottom of the tank in the center, 5 feet in diameter.

Sediment Outlet.—Approximately in the center of the bottom of the tank was a 4-inch flange connection to a sediment pipe leading down beneath the filter tank platform. A valve was originally placed on the end of this pipe, and on March 8 another valve was connected to it, 6 feet from the tank.

Effluent Outlet.—A 4-inch outlet, vertically above the original outlets and 2.5 feet below the top of the tank, connected with an extension of the original vertical riser used as an outlet pipe.

Float.—A telltale float was provided to show the level of the water in the tank during regular operation.

Connection to Filters.—The vertical riser, the original outlet pipe, was disconnected just above the ground, and a new 6-inch pipe above ground conveyed the effluent of the precipitation tank to the sand filter.

Period of Precipitation.—This tank held practically 12 hours' flow of water at the normal rate; and the evidence indicated that the average actual period of precipitation was about 11 hours, at the regular rate of flow, as judged by the time taken for passage through the tank.

Sand Filter.

The tank (10 feet deep and 11.78 feet in diameter), formerly used for filter No. 14 (north tank in middle row), was moved about 10 feet south, and elevated about 8.7 feet above the platform. The inside was covered with two coats of asphalt paint, and it was arranged as the sand filter, of which the principal features are as follows:

Bottom.—The bottom was level.

Underdrains and Supporting Layers.—Two layers of unpressed brick were placed flat in the bottom of the tank. The bricks in the lower layer were placed with their long dimension running north and south; and the space between the ends of the bricks in this direction was one inch, and in the east and west direction the space between the sides of the bricks was 4 inches. The bricks of the second layer were laid at right angles to the first layer, and they were originally placed as close together as they could get them. Above the bricks were placed 6 inches in thickness of graded gravel, as follows:

1. Three and a half inches of coarse stone, such as was used in the original English filters.

2. One inch of coarse gravel, not passing through a screen with a 0.5-inch mesh.

3. One and a half inches of fine gravel, passing through a 0.5-inch mesh, but not through screens with meshes of 0.17 to 0.125 inch.

The two upper grades of gravel were obtained by screening walnut and pea gravel, which was on the grounds.

Sand Layer.—The sand layer was 35 inches in thickness, made up as follows:

1. Eighteen inches of screened bank sand, furnished by the Engineering Company, having an effective size of 0.30 mm. and a uniformity coefficient of 2.5.

2. Seventeen inches of washed coarse sand from the original English filters, having an effective size of 0.34 mm. and a uniformity coefficient of 1.8.

The sand layer settled about 10 per cent of its thickness during operations; and on March 24 about 3.5 inches of sand was added to maintain the normal thickness.

Modified Underdrains.—When this system was placed in operation it was quickly learned that the underdrains would

not allow the passage of water at the scheduled rate. Accordingly, on March 3, the brick underdrains at the bottom were re-arranged as follows:

The bricks were laid in two layers, and were the same as used originally. In both layers they were laid flat. The first or lower layer consisted of concentric rows with the long dimension laid tangentially and at a distance apart of one inch measured on the circumference. These concentric rows were placed 4 inches apart, so that the radial distance from center to center of bricks was 8 inches. The top layer was laid with the long dimension of the brick radially, making a brick extend from the center of one brick to the center of the one in the next adjacent row. The distance apart circumferentially of the bricks was 0.5 inch.

The whole area of the filter was covered in this manner, with the exception of a brick conduit which led from the outlet pipe to the central upright of the agitator. The dimensions of this conduit were 4 by 8 inches on the inside, and it was so formed that the radial distance between the bricks was one inch, and the margin between the bricks of the cover was 0.5 inch.

The 6-inch layer of gravel and stone was resifted, and the respective grades were placed on the bricks as in the original construction. The two layers of sand, namely 18 inches of sifted bank sand (30 mm. effective size) and 17 inches of river sand (0.34 mm. effective size), were somewhat mixed in removing them from the filter, but were returned as nearly as practicable in their former condition.

Inlet.—The inlet (4-inch) was on the west side, about 2 feet below the top, entering the tank about one foot when it turned downward, and ended about 5 feet below the top of the tank and about 1.4 feet above the original top of the sand layer.

Outlet.—The effluent outlet pipe and the wash-water inlet pipe (4-inch) were on the south side of the tank, 4 inches above the bottom.

Wash-water Outlet.—This was a 6-inch pipe placed in the center of the bottom of the tank. On the inside of the filter this pipe was enlarged to 8 inches, and extended vertically to about one inch above the original sand surface. At the upper end of this pipe was a sleeve into which loosely fitted the lower arm of a 6-inch cross. Into the two horizontal arms of this cross (supported from the top by a vertical shaft) were 6-inch pipes 5 feet in length, capped at the ends, and serving as rake arms for the agitator. In each of these arms (pipes) on alternate sides was a horizontal slot, ranging in width from 1.5 inches to 0.5 inch from the end toward the center. During washing these rake arms (pipes) revolved near the sand surface, and the wash water was removed through the horizontal slots leading to the vertical center pipes and through two 1.75-inch holes in the cross.

Agitating Devices.—On the upper arm of the cross above described was a plug into which was set a 2.37-inch vertical shaft, leading to the operating gears where the shaft was supported upon timbers placed across the top of the tank. The movement was obtained from a countershaft operated by a belt and pulley from a 5-horse-power engine; and by a pulley, pinion (5 inches in diameter with 12 teeth), and beveled gear (43 inches in outside diameter with 108 teeth). The movement was in a right-handed direction only.

The teeth on each rake arm (slotted pipe) were 10 in number, 8 inches long, and 1.75 inches in diameter. They reached to within 2.2 feet of the bottom of the sand layer—that is, 5 inches below the normal surface, and 1.5 inches below the surface after the sand had settled before refilling.

Effluent Connection to Polarite Filter.—The effluent pipe branched about 4 feet in front of the tank, where separate inlets were provided for each of the two tanks of the polarite filter.

Polarite Filter.

As the rate of filtration in this filter was originally only half of that in the sand filter, it was necessary to arrange two tanks for the polarite filter, although they are operated as one filter. The leading features are as follows:

Tanks.—Two 8-foot tanks (formerly occupied by filters No. 5 and No. 8) were lowered on to the floor, and moved to the north to make them come as close as possible to the sand filter. The top of the tanks came about 5 inches below the bottom of the first filter. Each tank was coated on the inside with asphalt paint.

Construction of Filters.—Excepting in the layer of filtering material placed above the gravel, these filters were practically a duplicate of the sand filter above described. Owing to the thicker sand layer, the vertical central wash-water pipe and the agitator were 4 inches higher above the bottom than in the sand filter.

Sand Layer.—The sand layer, or filtering material, in each filter above the gravel was as follows:

1. Six inches of washed medium sand from the original English filters of an effective size of 0.27 mm. and a uniformity coefficient of 1.5.

2. Twenty-four inches of a mixed layer in equal portions of medium sand and polarite. The latter is a filtering material placed on the market in England, and is described quite fully, with results of analyses, in various reports. It is black, hard, and more or less porous, with a somewhat variable composition. It is prepared from a special iron ore by a patented process.

The effective size of the grade used here was 1.8 mm. and the uniformity coefficient 2.7.

3. Six inches of medium sand, as above described.

4. One and a half inches of fine crushed quartz of an effective size of 0.22 mm. and a uniformity coefficient of 1.8.

During operation, of course, the various layers of filtering material were mixed together to a considerable degree by washing and agitation.

Modified Underdrains.—Towards the close of the official test it was decided by the Engineering Company to operate the polarite filter at the same rate as in the case of the sand filter. Accordingly, one of the two tanks which had previously been operated together was thrown out of service. It was found, however, that the underdrains would not allow the desired quantity of water to pass the filter, and on April 17 the brick underdrains were re-arranged in a manner substantially the same as has been described for the sand filter. For some reason which was not definitely learned this change was only partially successful.

Inlets.—Each branch of the effluent pipe from the sand filter discharged (until April 17) into a semi-circular galvanized trough, about 8 inches in diameter and 9.5 feet long, extending across the tank about 3.6 feet above the sand surface. This trough was perforated with 0.10-inch holes, spaced about 0.50 inch apart. To maintain the same head on each filter the two tanks were connected by a 4-inch pipe just above the sand layer.

Outlet.—Each polarite filter had a 3-inch outlet pipe on the south side of the tank about 6 inches above the bottom. The separate outlets united above the platform into a 4-inch pipe on which was a meter, and through which the filtered water was discharged into a barrel beneath the platform. From the

barrel there was a connection to the trough in the old meter-room, and thence to the Third Street main and also to the sewer.

Wash-water Tank.—The 8-foot tank formerly occupied by filter No. 5 remained in its original position, and was used as a storage tank for wash water. It was filled with polarite filter effluent by pumping, the suction of the pump being placed in the barrel beneath the platform.

Wash-water Pump.—A duplex pump 7 by 6.75 by 8 inches was placed on the filter platform about midway on the west side. It was so connected that it could pump filtered water from the barrel into the wash-water tank; it could pump wash water from this tank (4-inch delivery pipes) through the effluent pipes into each of the filters; and it could also pump filtered water into the lime tanks. For the latter purpose it was not used after March 18.

Engine.—To agitate the sand in the filters a 5-horse-power upright engine was placed on the west side of the platform, provided with suitable belts, pulleys, and shafting.

Boiler.—A 20-horse-power upright boiler was placed on foundations just west of the filter platform, about midway of its length, and covered by a temporary shed.

Carbonic-acid Devices.

As stated at the outset of this section, the application of carbonic acid was not a part of this system or process during the early portion of the official test, and during the latter part of the test it was in an experimental stage. In practice it is stated by the Engineering Company that the carbonic acid would be obtained from kiln gases with the lime burnt at the purification works. To do this at the experimental plant was impracticable, and the carbonic acid was obtained in a liquefied

form, in iron holders containing about 50 pounds each. At the outset of its use the means of controlling the application of the gas were not at all satisfactory. At first two holders were connected at a time with regulating valves and gages. It was soon found to be necessary to have a steam connection to guard against freezing at the orifices. From time to time improvements were made in handling this gas, and beginning on April 13 a battery of six holders was used.

From March 30 to April 1 the carbonic acid was applied to the river water through a 0.25-inch pipe, tapped into the L on the inlet river-water pipe just as it left the ground and about 60 feet from the mouth of the pipe.

The carbonic acid was applied from April 2 to 12 to the mouth of the pipe conveying the effluent of the precipitation tank on to the sand filter. The 0.25-inch pipe passed through the L on the end of this vertical pipe, and extended into it about 6 inches.

From April 13 to the close of the test the carbonic acid was applied to the effluent of the sand filter. This effluent pipe entered at the top through a flange connection into a cask about 3.5 feet high and about 3.2 feet in diameter, and extended down to within 0.5 foot of the bottom. The 0.25-inch carbonic-acid pipe, with numerous small perforations on the upper 0.4 foot of its length, extended up into this inlet pipe about 1.25 feet. From this cask the filtered water was conveyed on to the polarite filter by a pipe which was connected to the head of the cask by a flange.

SECTION III.

Description of the Operation of this System of Purification and its Modifications.

From the outline of this system, which was given at the beginning of Section II, and from the description of the devices, the manner of operation of this system, for the most part, will be readily understood so far as the more important features are concerned. But as a matter of record the practical operation of the system is given in some detail, as follows:

Slaking the Lime.

There was put into the slaking tank a prescribed volume of commercial quicklime, which was slaked by the gradual application of river water, and during which the contents of the tank were stirred by hand. The volume of lime which was used differed from time to time, in part due to the difference in size of the two solution tanks, and in part due to different amounts of calcium oxide (CaO) contained in the commercial product.

As the sole object of the use of quicklime was to furnish a solution of saturated lime water, it is obvious that the quicklime should be as rich in calcium oxide as practicable. Such lime is known commercially as fat lime, and is not readily secured, as there is very little local market for it. Special effort was made to get fat lime, most of which came from Louisville.

Composition of Quicklime.

Analyses were made of several lots of lime used, and the results showed that the amounts of available calcium oxide (CaO) ranged from 55 to 90, and averaged about 80 per cent. The remainder consisted principally of insoluble residue (siliceous matter) and calcium carbonate, of which the latter was due to air-slaking. The last-named constituent was an important one in only one lot.

Preparation of Lime-water Solutions.

Saturated solutions (practically speaking) of lime water were prepared alternately in the two solution tanks. The slaked lime was allowed to flow slowly through a small gate on the slaking tank into an open wooden trough, whence it was washed into the respective solution tank by a stream of river water (filtered water prior to March 19). This operation required the constant attention of a laborer. The solution subsided and became clear, practically speaking, before using, although a thin pellicle of calcium carbonate formed upon the surface of the liquid.

In the preparation by hand of saturated solutions of lime water there is unavoidably some wastage of lime (calcium oxide). Under favorable conditions, by this method the wastage ought not to exceed about 5 per cent, but it is estimated that during the official test about 10 to 15 per cent of the lime used was wasted. With mixing machines, such as are used on a large scale, it is said that this wastage ought not to exceed much over one per cent.

At the close of the official test the 6-foot solution tank, which had not been cleaned during the work, was found to contain on the bottom from 4 to 12 inches of sludge. A

considerable portion of this consisted of suspended matters removed from the river water used in preparing the solutions. Of the remaining and smaller portion most of it came from the siliceous matter in the slaked lime.

Strength of Lime Solutions.

During this official test 82,837 cubic feet (619,621 gallons) of lime water were used, having an average strength of 64.3 grains of calcium oxide (CaO) per U. S. gallon. This corresponded to a total of 5,700 pounds of calcium oxide, or 7,100 pounds of commercial quicklime of the average composition used.

In the following table is recorded the strength of each tankful (lot) of lime-water solution, together with the date on which use of each was begun. The use of a tankful of solution ended at the commencement of the use of the following lot. The samples were collected from a pet-cock on the lime-water pump, when the tank was about half empty. As a rule the solutions were fairly clear, and the strength was determined on the unfiltered sample by titration against a standard solution of hydrochloric acid, using phenol-phthalein to indicate the neutral point. In the event that there was present any undissolved calcium oxide it would appear in the result: but this is fair, because when the solution reached the river water it was doubtless dissolved and full benefit derived rom it.

Table showing Strength of Lime-water Solutions.

Number of Lot.	Date when use of each Lot (Tankful) was begun.	Strength of Solution. Grains per Gallon of Calcium Oxide (CaO).	Number of Lot.	Date when use of each Lot (Tankful) was begun.	Strength of Solution. Grains per Gallon of Calcium Oxide (CaO).
1	March 13, 1899, 5:40 PM	62.3	63	April 3, 1899, 8:33 PM	50.8
2	" 13, " 7:40 PM	64.8	64	" 4, " 1:25 AM	60.3
3	" 14, " 3:21 AM	63.6	65	" 4, " 8:30 AM	61.0
4	" 14, " 9:25 AM	64.2	66	" 4, " 1:33 PM	62.3
5	" 14, " 5:35 PM	74.4	67	" 4, " 10:15 PM	65.6
6	" 14, " 11:35 PM	66.4	68	" 5, " 3:15 AM	63.2
7	" 15, " 6:20 AM	65.2	69	" 5, " 9:35 AM	67.5
8	" 15, " 1:30 PM	61.6	70	" 5, " 3:22 PM	66.4
9	" 15, " 12:00 PM	63.0	71	" 5, " 11:30 PM	65.6
10	" 16, " 5:05 AM	65.2	72	" 6, " 4:50 AM	64.3
11	" 16, " 5:05 PM	65.6	73	" 6, " 2:10 PM	69.4
12	" 16, " 11:30 PM	64 9	74	" 6, " 7:40 PM	63.6
13	" 17, " 5:19 AM	64.9	75	" 7, " 4:28 AM	69.4
14	" 17, " 11:10 AM	68.8	76	" 7, " 10:20 AM	66.8
15	" 17, " 7:30 PM	65.6	77	" 7, " 6:20 PM	64.3
16	" 18, " 1:20 AM	67.8	78	" 7, " 11:50 PM	61.6
17	" 18, " 9:04 AM	67.5	79	" 8, " 7:30 AM	71.5
18	" 18, " 6:26 PM	67.8	80	" 8, " 12:50 PM	68.9
19	" 19, " 6:30 AM	64.3	81	" 8, " 8:45 PM	66.3
20	" 19, " 9:51 AM	65.6	82	" 9, " 2:50 AM	61.6
21	" 19, " 8:55 PM	67.8	83	" 9, " 11:25 AM	72.7
22	" 20, " 5:39 AM	66.5	84	" 9, " 4:42 PM	55.1
23	" 20, " 6:00 PM	65.6	85	" 10, " 1:00 AM	71.5
24	" 21, " 1:43 AM	64.9	86	" 10, " 6:24 AM	57.0
25	" 21, " 12:07 PM	69.4	87	" 10, " 12:30 PM	65.6
26	" 21, " 8:47 PM	55.7	88	" 10, " 9:20 PM	54.4
27	" 22, " 7:18 AM	68.4	89	" 11, " 6:41 AM	71.1
28	" 22, " 3:58 PM	59.6	90	" 11, " 1:55 PM	64.9
29	" 23, " 3:00 AM	55.4	91	" 11, " 11:20 PM	74.4
30	" 23, " 11:00 AM	58.0	92	" 12, " 5:30 AM	69.4
31	" 24, " 12:17 AM	61.6	93	" 13, " 12:40 AM	68.8
32	" 24, " 6:45 AM	59.0	94	" 13, " 7:00 AM	70.1
33	" 24, " 8:45 PM	61.0	95	" 13, " 3:20 PM	72.1
34	" 25, " 4:33 AM	56.4	96	" 13, " 10:17 PM	70.8
35	" 25, " 3:30 PM	61.3	97	" 14, " 7:23 AM	70.8
36	" 25, " 11:20 PM	57.7	98	" 14, " 1:35 PM	68.5
37	" 26, " 9:20 AM	58.5	99	" 15, " 8:20 AM	68.8
38	" 26, " 5:30 AM	59.6	100	" 15, " 9:15 AM	67.5
39	" 27, " 4:55 AM	62.2	101	" 15, " 5:55 PM	70.8
40	" 27, " 1:50 PM	59.6	102	" 15, " 11:40 PM	66.3
41	" 28, " 2:00 AM	61.6	103	" 16, " 9:40 AM	74.1
42	" 28, " 10:28 AM	59.0	104	" 16, " 4:14 PM	66.3
43	" 28, " 10:26 PM	63.3	105	" 17, " 1:25 AM	67.8
44	" 29, " 6:13 AM	59.6	106	" 18, " 5:10 AM	62.3
45	" 29, " 4:03 PM	62.9	107	" 18, " 4:30 PM	70.8
46	" 29, " 11:10 PM	63.5	108	" 19, " 12:25 AM	66.8
47	" 30, " 10:30 AM	64.2	109	" 19, " 9:50 AM	70.8
48	" 30, " 5:48 PM	67.0	110	" 19, " 7:35 PM	61.3
49	" 31, " 3:53 AM	64.9	111	" 20, " 7:35 AM	69.4
50	" 31, " 9:49 AM	54.5	112	" 20, " 5:35 PM	66.3
51	" 31, " 6:30 PM	62.9	113	" 21, " 5:40 AM	69.4
52	April 1, " 1:07 AM	25.6	114	" 21, " 2:00 PM	63.6
53	" 1, " 8:30 AM	69.8	115	" 22, " 3:00 AM	70.0
54	" 1, " 4:25 PM	45.3	116	" 22, " 10:52 AM	64.9
55	" 1, " 9:49 PM	66.3	117	" 22, " 10:45 PM	70.8
56	" 2, " 1:45 AM	59.0	118	" 23, " 7:55 AM	64.9
57	" 2, " 7:35 AM	67.8	119	" 23, " 7:30 PM	70.0
58	" 2, " 1:12 PM	51.8	120	" 24, " 3:50 AM	56.8
59	" 2, " 8:20 PM	62.9	121	" 24, " 3:30 PM	70.8
60	" 3, " 12:50 AM	62.3	122	" 24, " 11:50 PM	53.1
61	" 3, " 7:23 AM	74.4	123	" 25, " 11:50 AM	71.5
62	" 3, " 1:17 PM	55.6			

Amount of Lime Water applied to the River Water.

Theoretically there was added enough lime water to combine with the carbonic acid in the river water, and to furnish a sufficient excess to coagulate thoroughly the suspended matters in the river water. Owing to the fact that the amounts of carbonic acid and of suspended matters in the river water are very variable, it was necessary to change frequently the rate of application of lime water, in order to have the effluent of the precipitation tank coagulated to a proper degree and without a great waste of lime. The evidence indicates that the coagulated water as it entered the sand filter should contain about 25 parts per million of suspended matter to yield the best results. Amounts of suspended matter in excess of this were repeatedly obtained, but the system was not then operated to its best advantage.

Quantities of suspended matter less than about 25 parts per million in the effluent of the precipitation tank apparently were not necessary.

A comparison of the results of the analyses of this effluent (see Table No. 6, Section IV) with the above shows at once that in the practical operation of this system no especial attention was paid to the relation between the amount of suspended matter in the river water and the excess of applied lime water. In fact, the only guide used in the application of the lime was the appearance of the water as it left the precipitation tank and as drawn from a series of taps on the side of the tank. These taps were placed 12.8, 17.6, 22.1, and 27.9 feet from the bottom of the tank, and at the regular rate of operation corresponded to 4.5, 6.2, 7.8, and 9.9 hours of subsidence, respectively. In Table No. 5 of Section IV

are given the results of a series of analyses of samples of water collected at the several points in its passage through the tank.

During the official test the amount of applied lime (CaO) ranged from 6.8 to 2.7, and averaged 4.7 grains per gallon of river water. As the river water was used for the preparation of the lime-water solution, the quantity of river water in these records includes the quantity of lime-water solution.

So far as the amount of suspended matter in the river water is concerned, the maximum was about as great during this test as would probably be ever met with in the practical operation of a purification plant, although it is a fact that very rarely there might be greater amounts of coarser matter for short periods. But, owing largely to the season of the year, there would doubtless be occasions when the same maximum amount of suspended matter in the river water would have to be treated, and when the carbonic acid in the river water would be materially greater in amount than was the case during this test. It is estimated that occasionally it would be necessary to apply to the river water 10 grains per gallon of lime (CaO).

The question of the annual average amount of applied lime which would be needed is taken up beyond in connection with the full data.

Percentage of River Water which would be required for the Preparation of Lime-water Solutions.

On the basis of 64 grains per gallon as the average strength of the lime-water solution, the percentage of river water which would have to be diverted under pressure from the main to the lime-water tanks, and as lime water would subsequently

have to be pumped to the precipitation tank, apparently, would be as follows for the range of application which this river water would require:

Grains of Lime (CaO) per Gallon.	Percentage of River Water required.
3	4.7
4	6.3
5	7.8
6	9.4
7	10.9
8	12.5
9	14.1
10	15.6

With the devices used in the test the height to which the lime water was elevated was 50 feet. In practice devices could be arranged so that this distance would be very materially reduced, and possibly done away with altogether.

Operation of the Precipitation Tank.

This tank was operated on the continuous displacement plan. The river water and lime water were mixed in a gutter at the top and conducted through a standpipe to the bottom, whence the mixed water rose through practically the full height of the tank, and was removed through a side outlet pipe 2.5 feet from the top. It was intended to keep the water level about 15 inches below the top of the tank; and although the meter on the inlet pipe was broken before the test began, the fairly constant pressure in the river-water pipe allowed this to be

accomplished in a reasonably satisfactory manner with the aid of the meter on the final effluent.

At the beginning of this test the water in the precipitation tank had been settled for four or five days, and on April 17 the water had an opportunity to subside for about 20 hours while repairs were being made. Although there were several occasions when the continuous operation of the tank was unavoidably interrupted for several hours at a time, the intermittency of its operation was not a fact of practical significance except on the occasion first mentioned.

Inspection of the mixing gutter at the close of the test showed that there was a layer of mud about 0.06 inch thick on the bottom, and a slight amount of carbonate of lime near the point where the lime water was applied.

No regular procedure was adopted with reference to the removal of the accumulated sediment at the bottom of the tank. On April 1 the tank was drained because the water with which it was filled contained too small an excess of lime. After draining inspection showed that the sediment upon the sides of the wooden hopper and on the bottom of the tank in the center had all been removed, practically speaking. Towards the close of the test the valve on the sediment pipe was opened, but the pipe was so much obstructed that no flow resulted. In practice a precipitation tank should not be allowed to go for such a long period without the removal of the sediment at the bottom.

With reference to the amount of water necessary to be wasted in flushing out this sediment, no definite data were obtained during this test.

From March 13 to April 25, inclusive, there were passed through this tank 9,163,845 gallons of river water, containing

on an average 273 parts per million of suspended matter. The effluent of this tank on an average contained 35 parts of suspended matter, which corresponds to a deposition of 18,200 pounds of sediment. It is also estimated from the analytical evidence that during this period of official test there were precipitated 6,500 pounds of carbonate of lime. This estimate not only includes the carbonate of lime formed from the combination of the lime water with the free and half-bound carbonic acid of the water, but also that in the river water which was rendered insoluble by the removal of the half-bound carbonic acid.

Operation of the Sand Filter.

The operation of the sand filter for the most part was similar to that of the conventional filter of the American type, which has been fully described recently in a number of reports. It differed somewhat in the details of operation, which are briefly reviewed as follows:

Rate of Filtration.—The normal rate of filtration was 100 million gallons per acre daily, although at times, especially during the first few days of the official test, the rate was materially less than the normal.

Maintenance of Water Level above the Sand.—This was accomplished by hand regulation of a valve, and the water level ranged from 5.8 to 0.7 feet above the sand surface. In a general way it was the custom following a washing or agitation of the filter to operate with a shallow layer of water, and allow it to increase as the loss of head increased.

Regulation of the Rate of Filtration.—The rate was controlled solely by the hand regulation of the valve on the outlet pipe. As there was no meter provided at this point, it was necessary

to use as a guide the variations in the water level upon the polarite filter, the effluent of which was measured. When the influent to the sand filter was thoroughly coagulated, and contained about 25 parts per million or less of suspended matter, the influence upon the quality of the effluent of the resulting variations in rate was almost *nil*. The variations, however, were quite marked at times, as will be seen from Table No. 7 of Section IV.

Head Utilized.—The normal available head was practically 10 feet, measured from the maximum water level above the sand to the discharge level of the outlet pipe. Owing to the absence of accurate control of the rate of filtration, there were many occasions when the rate was allowed to fall below the normal just prior to agitation or washing. At such times it would have been necessary to have employed a head of 11 to 12 feet, in order to have maintained the filter at its rated capacity.

Agitation.—With this filter the operators employed, so far as practicable, agitation of the upper portion of the sand layer before resorting to washing, in order to relieve the clogging of the sand and maintain approximately the normal rate of filtration. Owing to the thorough coagulation of the influent water it was possible to take full advantage of this procedure; and in no instance were there signs of the water "breaking through" in places so as to give a markedly turbid effluent when the available head was only partly utilized.

Agitation consisted in revolving from one to three times the rake arms, the teeth of which penetrated the sand layer normally to a depth of about five inches. The inlet and outlet valves were closed during this operation, which ordinarily occupied about one minute. No water above the sand was

wasted or run out of the filter. One of the advantages of this procedure was that it liberated considerable entrapped air.

Washing.—As a rule, under normal conditions, and with no important exceptions, the sand filter was washed when the last agitation failed to allow the normal rate to be maintained for as long as two hours. The first step in washing was to close the valve on the inlet pipe, and allow the water above the sand to filter out until it stood about 0.7 foot above the level of the slots in the rake arms (pipes) of the agitator, when the outlet valve was closed. The agitator was then slowly revolved for five minutes. At the end of this time the valve on the sewer pipe was opened, and the dirty water standing above the level of the slots was wasted. This water was previously treated with chemical, of course, but was not filtered. Filtered water was then pumped into the filter for about ten minutes as a rule, the volume of water used at a washing being about 2,500 gallons. The normal rate at which the wash water was pumped into the filter was about 250 gallons per minute, equal to 145 million gallons per acre daily. On the basis that the sand layer during washing contained 45 per cent of voids, the lineal velocity of the wash water was normally about 0.7 foot per minute. The pressure of the wash water in the brick underdrains was six feet, or about two feet in excess of the pressure of the water column above them.

Upon stopping the wash-water pump the agitator was also stopped, the valve on the sewer pipe closed, and the valve on the inlet pipe opened. As a rule, the valve on the effluent pipe was opened when the water had risen to about three feet above the sand surface.

The period occupied in washing the sand filter ranged from 60 to 18, and averaged 34 minutes.

Non-wastage of Effluent after Washing.—Although there was some deterioration in the quality of the effluent just after agitation and just after washing, it was not sufficient to justify its wastage; and no effluent was allowed to go to waste.

Operation of the Polarite Filter.

In general principle the operation of the polarite filter was similar to that of the sand filter, but differed somewhat in several details, as follows:

Rate of Filtration.—The normal rate of filtration was 50 million gallons per acre daily until April 17, after which date it was increased to 100 million gallons per acre daily. The actual rate, however, was materially less than this on a number of occasions.

Maintenance of the Water Level above the Sand.—Until April 17 the water ordinarily stood only about 1.5 feet above the sand surface, in order to get as much aeration as possible of the water as it was applied from the perforated gutters. Beginning on April 18, these gutters were removed, and the water ordinarily stood about three feet above the sand.

Regulation of Rate of Filtration.—As there was a meter on the effluent pipe of this filter, the hand regulation of the outlet valve gave a more uniform rate than in the case of the sand filter.

Head Utilized.—The normal available head in this filter was 11.0 feet, measured from the maximum water level above the sand to the level of the discharge of the effluent pipe. Of this distance 3.5 feet were below the bottom of the filter. Owing to the manner of operation of the filter prior to April 18, the full head was not availed of.

Agitation and Washing.—This filter was not agitated or washed enough to develop any systematic procedure, but it was operated in this respect quite similarly to the sand filter, as just described. By far the greater part of the clogging was due to accumulations of air within the filter. This was very apparent, as it caused marked fluctuations of the water level in the pressure gages, in some instances as much as 0.3 foot. After April 18, when the filter was filled from the top instead of the bottom, the clogging was entirely due to entrapped air caused thereby, and this was removed by pumping in 0.6 foot in depth of filtered water from below, but the water was not wasted.

Non-wastage of Effluent.—Although none of the effluent of this filter was wasted, it showed a tendency just after washing to contain sand and fine black particles coming from the polarite. After washing the surface of the water above the sand contained a black scum, which had to be skimmed off.

Application of Carbonic Acid.

The application of carbonic acid was controlled, in a measure, by the pressure of the gas in the pipe as it entered the water. Independent of freezing of the orifices, the control was not as close as it should have been to give the results required in practice, even with a man standing at the regulator during the greater part of the time.

When the gas was applied to the inlet pipe of the sand filter there was a considerable wastage of gas, due to its passage through the water in the form of bubbles, the interior of which was not available for acting upon the water.

The results of analysis of the water were the only guide as to what pressure to maintain at the regulator.

Both with regard to the control of the application of the carbonic-acid gas and its thorough mixture with the water, this process was not adequately worked out during the official test, and would require further attention before the construction of a large plant. After April 13, when the gas was applied in a closed cask, the operation was apparently much improved over its earlier status.

Supervision and Attendance.

This system of purification was operated under the supervision and direction of Mr. John MacDougall, who took immediate charge of the plant during the day. At night it was under the charge of Mr. Archibald MacDougall. Two attendants were constantly required—one to operate the boiler, engines, and pumps, and the other to operate the filters and carbonic-acid devices. During the day two laborers were also employed, one of whom was occupied partly in the preparation of lime solutions. The Engineering Company also availed itself of the services of a chemist, Mr. M. L. Trowbridge, who procured for them analytical evidence from time to time on special features, especially with reference to the application of the carbonic acid.

SECTION IV.

Explanation and Tabulation of the Results accomplished by the Systems during the Official Test.

This section deals solely with the complete detailed records of the results accomplished by this system during the official test, both with regard to the efficiency which it showed and the elements of cost so far as they were actually met. Summaries of the evidence along these two lines are summarized and discussed in the following sections, respectively.

During the period of preliminary operation a general record was kept of the results accomplished, but no features were developed which were not more adequately brought out by the results of the official test.

The official test covered the period from March 13 (5:40 P. M.) to April 25 (6:00 P. M.), a period of 43 days. Of this period 40.41 days were devoted to regular operations, while the remaining time, 2.76 days, or 6.4 per cent of the period, was occupied by delays, a list of which is as follows:

March 15...3.67 hours, due to stopping river-water pumps.

March 16...2.67 hours, due to replacing injector on steam boiler by a small pump.

March 18....1.37 hours, due to making connection of pipe used to deliver river water to lime tanks.

Mar. 24–25..3.43 hours, due to repairs on regulating machinery, and adding sand to sand filter to compensate for settling of sand layer.

March 27....0.87 hour, due to making (carbonic-acid) gas connection to the inlet pipe of the precipitation tank and to repair lime meter.

March 30....0.25 hour, due to making connection to inlet of the precipitation tank to obtain river-water samples.

April 1.....15.32 hours, due to draining and refilling the precipitation tank.

April 2.....5.00 hours, time occupied in filling the precipitation tank.

April 4.....1.20 hours, time occupied in extending the carbonic-acid gas discharge further into the inlet of the sand filter.

April 7.....0.83 hour, due to stopping river-water pumps.

April 12.....9.50 hours, time occupied in making necessary changes to apply carbonic acid to the water between the sand and polarite filters.

April 14.....2.67 hours, time occupied in making changes in the effluent pipe of the polarite filter to double rate of filtration.

April 17–18..18.8 hours, due to reconstruction of the underdrains of the polarite filter.

April 22.....0.37 hour, due to stopping of effluent meter by sand.

List of Tables containing the Result of the Official Test of this System.

For the composition of the Ohio River water treated during this test reference is here made to the table of analyses presented in Section I (pages 496–497).

In this system of purification especial importance is attached to the determination of the carbonic acid present in the river water. The results in the table of river-water analyses show all of this constituent which is capable of combining with lime water. One grain of lime (calcium oxide) to one gallon of water will combine with 13.5 parts per million of carbonic acid. These results represent both the "free" carbonic-acid gas, which, dissolved in water, forms free carbonic acid, and also the "half-bound" carbonic acid,

which may be engaged in holding carbonate of lime in solution in the form of the bicarbonate.

A complete record of the results of the official test is presented in a series of ten tables, which are listed as follows:

Table No. 1.—The quantitative records of operation of the system by calendar days.

Table No. 2.—A summary of the qualitative results of operation of the system, corresponding to calendar days.

Table No. 3.—The records of agitations and of washings of the sand filter.

Table No. 4.—The records of agitations and of washings of the polarite filter.

Table No. 5.—The results of examinations of special samples of the effluent of the precipitation tank collected at different distances from the bottom of the tank.

Table No. 6.—The results of daily chemical and bacterial analyses of the effluent of the precipitation tank.

Table No. 7.—The results of bacterial and special examinations of the effluent of the sand filter.

Table No. 8.—The results of bacterial and special examinations of the effluent of the polarite filter.

Table No. 9.—The results of chemical analyses of the effluent of the sand filter.

Table No. 10.—The results of chemical analyses of the effluent of the polarite filter.

Totals and averages of all the more important results will be found at the foot of tables No. 1 and No. 2.

The tables will be found beyond, beginning on page 536.

Methods of Analyses.

The methods of analyses used during these tests were the same as used on earlier work here, and have been described

in the previous report. The only new determination was that of the amount of lime (calcium oxide) present in excess in the effluents. This was determined by titrating a known volume of water against an acid solution of known strength, using an alcoholic solution of phenol-phthalein to indicate the neutral point.

Explanation of Tables.

For the most part the data presented in this series of tables will be readily understood. However, there are a number of conditions and special features which it is desired to record, as follows:

Table No. 1.— This table contains the periods of time devoted to the operation of the system, the period of subsidence employed in the precipitation tank, with quantities of water and of lime for each calendar day.

The quantity of total effluent was obtained by meter measurement. As there was no meter on the inlet to this system, the applied river water for each day was taken as that of the total effluent, after making corrections, if necessary, for differences in the water level at midnight in the several portions of the system. To facilitate this correction there is recorded for each day at midnight, as shown in the table, the quantity of water in the purification tank above the outlet pipe and in the filters above the sand layers.

The quantity of wash water is subdivided into unfiltered and filtered wash water, both obtained by gage measurements. The unfiltered wash water was due to the custom followed in washing, as described in the last section.

The actual rate of filtration is based on the total quantity of effluent and the time that the filter was in service (time of

washing excluded). The net rate of filtration is based on the total quantity of effluent minus the filtered wash water, and the total time minus legitimate delays, but not the time of washing.

The quantity of lime water was obtained by meter measurement, and of each tankful of lime water a sample was collected for analysis to show its strength when the tank was about half emptied. The detailed results of these analyses have been presented in Section III. The remaining columns of figures will explain themselves.

Table No. 2.—This table contains a daily summary of the results, showing the qualitative efficiency of the system, based on the averages of the detailed analytical evidence presented in subsequent tables. The averages for the effluents of the precipitation tank and each filter correspond to the river water for each calendar day. But as it took about twelve hours for the water to pass through the precipitation tank, the results from all of the effluents are averaged from noon of each calendar day until noon of the following day. In this manner the delay of twelve hours for the passage of the river water through the precipitation tank was overcome, and all the data refer by days to the same water.

With regard to these daily average results it is to be stated that they include all of the analyses, except, as a rule, those samples of effluents collected for bacterial analyses within half an hour after the filters have been washed or agitated. In all cases the percentage was computed by dividing the difference in the quantity of the particular constituent present in the river water and in the corresponding portion of the given effluent by the quantity in the river water.

Concerning the excess of lime in the effluent of the filters,

it will be noted that repeatedly during the latter part of the test the results are recorded as 0, with another figure given in a bracket and marked with a star. The latter figure refers to total carbonate alkalinity due almost entirely to bicarbonate of lime. These figures were obtained by averaging the results of analyses made of individual samples, while the results obtained from mixed average samples are given in tables No. 9 and No. 10. In some instances there are slight discrepancies in the results, due apparently to changes which took place in the samples upon standing.

Tables No. 3 and No. 4.—These tables contain full records of agitations and washings of the filters. The washings are given serial numbers, and the agitations between washings are given the corresponding number to the next washing, but with successive subletters (a, b, c, etc.)

The data are self-explanatory, except that the loss of head before washing or agitating was computed as if the regular rate of filtration had been maintained uniformly. At such times the rates were occasionally allowed to drop, and this explains why the recorded losses of head are in excess of the available head (10 feet) on the sand filter.

Table No. 5.—To show the effect of the action of the lime water and of different periods of subsidence, there were collected from time to time special samples from four taps on the sides of the precipitation tank. These taps, numbered 1 to 4, beginning at the bottom, and distant from the bottom 12.8, 17.6, 22.1, and 27.9 feet, corresponded at the regular rate of flow to about 4.5, 6.2, 7.8, and 9.9 hours' subsidence, respectively.

Table No. 6.—The results of daily chemical and bacterial analyses of the effluent of the precipitation tank are given in

this table. The samples were collected regularly at 4 P. M., 12 P. M., and 8 A. M., or as near thereto as possible. The excess of lime, suspended solids, and the bacteria were determined on the three daily samples; while the three portions, in equal quantities, were mixed together for a sample from which the remaining determinations were made.

Tables No. 7 and No. 8.—In these tables are recorded the excess of lime, amount of suspended matter, and the number of bacteria in the individual samples of the effluent of the sand filter and polarite filter, respectively. Those samples designated by "R" were regular samples, and used in computing the daily averages. As a rule, no such samples were taken within half an hour after washing or agitating. It was the general plan to take at least three or four such samples daily, and from time to time to take samples every three hours for a period of about twenty-four hours.

In addition to the regular samples, special samples were taken after washing or agitating the filters, and when there had been filtered after washing (or agitating) 100, 250, 500, and 1,000 cubic feet of water. These quantities corresponded, at the regular rate of filtration, to intervals of about 4, 11, 22, and 44 minutes after washing (or agitating), respectively. These four special samples are designated as A-1, A-2, A-3, and A-4 after agitating, and W-1, W-2, W-3, and W-4 after washing, respectively.

Relative to their exclusion from averages, it is to be stated that while there was ordinarily some diminution in efficiency at these times, the effect in practice would scarcely be appreciable, owing to the dilution at such times of the particular effluent by the effluents of the other filters. During the last week of the test it was found that the numbers of bacteria in

the effluents were abnormally high, due to a bacterial growth in the wash-water tank.

In the case of the regular samples there is recorded the loss of head of the water in passing through the filter at the time that the sample was collected; and also the rate of filtration in million gallons per acre daily, based on the average quantity of effluent obtained during the preceding half hour.

Tables No. 9 and No. 10.—These tables contain the results of chemical analyses of the effluents of the sand filter and polarite filter, respectively. The samples were mixtures in equal portions of all "regular" samples collected during periods of forty-eight hours, corresponding to calendar days. The hours of collection of the portions are found in tables No. 7 and No. 8, respectively.

With reference to the alkalinity, it will be noted that the caustic alkalinity (expressed as calcium oxide—CaO) and the total alkalinity (expressed as calcium carbonate — $CaCO_3$) are given. On those occasions, when the effluents were caustically alkaline, the larger quantity of carbonate alkalinity was due chiefly to the different form of expressing the lime present as lime water; but it also was due slightly to the presence of normal carbonate of lime present in the effluent, even in the complete absence of carbonic acid. It was found that caustically alkaline effluents contained from 0 to 8, with an average of about three parts per million of normal carbonate of lime.

TABLE NO. 1.—*Summary of the Quantitative Results of Operation by Calendar Days.*

CALENDAR DAY—1899.	PERIODS OF TIME. HOURS. Operation including Washing.	PERIODS OF TIME. HOURS. Delays.	QUANTITIES OF WATER, IN CUBIC FEET. Total Effluent.	Water in Filters above Sand Layer and Tank above Outlet.	Wash Water. Lime Water.	Wash Water. River Water.	Wash Water. Unfiltered.	Wash Water. Filtered.	Wash Water. Total.	GALLONS PER 24 HOURS. River Water.	GALLONS PER 24 HOURS. Net Effluent.	Average Period of Subsidence of Water applied to Filter. Hours.	AVERAGE RATES OF FILTRATION MILLION GALLONS PER ACRE DAILY. Actual. Sand Filter.	Actual. Polarite Filter.	Net. Sand Filter.	Net. Polarite Filter.	PERCENTAGE WHICH WASH WATER WAS OF TOTAL EFFLUENT. Unfiltered.	Filtered.	Total.	Average Strength of Lime Water. Grains per Gallon.	Average Grains of Lime (CaO) per Gallon of River Water.
March 13....	6.33	0.00	6,388	1,228	644	6,388	00	00	00	182,000	182,000	108.0	73	36	73	36	0.00	0.00	0.00	59.0	5.9
" 14....	24.00	0.00	25,044	1,108	2,262	24,924	00	00	00	187,000	187,000	39.0	76	38	75	38	0.00	0.00	0.00	65.8	6.0
" 15....	20.33	3.67	20,159	863	2,117	19,914	218	213	431	177,600	174,000	19.4	74	37	70	35	1.09	1.07	2.16	64.3	6.8
" 16....	21.33	2.67	24,675	1,016	2,025	24,828	218	218	436	210,000	205,000	15.6	89	44	81	40	0.88	0.88	1.76	64.5	5.3
" 17....	24.00	0.00	30,099	1,076	2,469	30,159	218	251	469	226,000	222,000	12.8	94	47	89	44	0.72	0.84	1.56	66.3	5.4
" 18....	21.03	2.97	26,715	1,326	1,870	26,965	436	540	976	230,000	220,000	14.4	96	48	88	44	1.62	2.01	3.63	67.8	4.7
" 19....	24.00	0.00	31,524	459	1,823	30,657	218	267	485	230,000	233,000	12.6	98	49	94	47	0.71	0.87	1.58	65.8	3.9
" 20....	24.00	0.00	30,734	1,135	1,572	31,410	76	306	382	236,000	228,000	12.3	96	48	91	46	0.24	0.98	1.22	66.5	3.3
" 21....	23.68	0.32	28,573	1,041	1,725	28,479	76	289	365	217,000	212,000	13.6	91	46	85	42	0.27	1.01	1.28	66.0	4.0
" 22....	23.15	0.85	29,651	1,150	1,719	29,760	103	272	375	231,000	228,000	12.9	96	48	89	44	0.35	0.91	1.26	61.2	3.5
" 23....	23.15	0.85	29,886	644	1,608	29,380	283	512	795	229,000	226,000	13.1	98	49	90	45	0.95	1.71	2.66	57.3	3.1
" 24....	21.58	2.42	27,752	901	1,695	28,009	87	273	360	234,000	229,000	13.8	96	48	92	46	0.32	0.98	1.30	59.8	3.6
" 25....	22.99	1.01	28,700	1,276	1,707	29,075	224	556	780	227,000	219,000	13.3	96	48	88	44	0.77	1.91	2.68	58.7	3.4
" 26....	24.00	0.00	30,980	949	1,773	30,653	87	278	360	230,000	227,000	12.6	97	48	91	46	0.28	0.89	1.17	58.4	3.4
" 27....	23.72	0.28	29,832	1,325	1,596	30,208	147	495	642	229,000	229,000	12.8	97	48	92	46	0.49	1.66	2.15	60.6	3.2
" 28....	24.00	0.00	30,516	1,134	1,610	30,325	136	496	632	227,000	223,000	12.7	95	48	89	45	0.45	1.62	2.07	60.2	3.2
" 29....	23.13	0.87	29,380	1,363	1,764	29,559	98	273	371	230,000	225,000	13.1	97	48	89	45	0.33	0.92	1.25	61.6	3.7
" 30....	23.75	0.25	30,832	1,156	1,902	30,625	87	273	360	232,000	231,000	12.6	96	48	92	46	0.28	0.89	1.17	61.8	3.8
" 31....	23.97	0.03	26,295	1,189	2,018	26,328	338	889	1,227	197,000	187,000	14.6	86	43	75	38	1.29	3.38	4.67	59.4	4.5
April 1....	8.68	15.32	10,390	906	901	{10,106	00	00	00	280,000	280,000	10.3	112	56	112	56	0.00	0.00	0.00	30.4	2.7
					{*1539	{16,000*														57.0	5.2
" 2..	19.00	5.00	22,955	906	2,834	†	163	703	866	†	210,000	13.3	92	46	84	42	0.71	3.07	3.78	60.0	6.1
" 3....	24.00	0.00	30,610	1,129	2,703	30,833	103	338	441	231,000	226,000	12.5	97	48	90	45	0.34	1.10	1.44	60.0	5.3
" 4....	22.60	1.20	29,515	944	2,598	29,330	98	327	425	231,000	230,000	13.1	98	49	92	46	0.33	1.11	1.44	60.8	5.4
" 5....	24.00	0.00	32,935	1,009	2,667	33,000	00	00	00	248,000	248,000	11.7	99	50	99	50	0.00	0.00	0.00	65.6	5.3
" 6....	24.00	0.00	31,680	1,047	2,351	31,718	98	338	436	238,000	235,000	12.2	99	50	94	47	0.31	1.07	1.38	65.7	4.9
" 7....	23.17	0.83	31,590	1,161	2,290	31,704	00	00	00	247,000	247,000	12.2	99	50	99	50	0.00	0.00	0.00	66.3	4.8

April 8	24.00	0.00	32,176	867	2,462	31,882	152	332	484	239,000	238,000	12.1	98	49	95	48	0.47	1.03	1.50	66.8	5.1
" 9	24.00	0.00	32,518	948	2,387	32,589	00	00	00	244,000	244,000	11.8	100	50	98	49	0.00	0.00	0.00	62.6	4.6
" 10	24.00	0.00	33,853	1,362	2,290	34,267	00	00	00	253,000	253,000	11.3	101	50	101	50	0.00	0.00	0.00	62.4	4.2
" 11	24.00	0.00	31,773	1,101	2,045	31,512	98	327	425	236,000	235,000	12.2	97	48	94	47	0.31	1.03	1.34	63.5	4.2
" 12	14.50	9.50	20,260	1,548	1,262	20,707	120	338	458	257,000	246,000	19.0	102	51	98	49	0.59	1.67	2.26	71.2	4.3
" 13	24.00	0.00	31,619	1,177	2,121	31,248	120	278	398	234,000	234,000	12.2	97	48	94	47	0.38	0.88	1.26	70.0	4.8
" 14	21.33	2.67	25,927	1,351	1,737	26,001	00	338	338	219,000	216,000	11.9	94	47	86	43	0.00	1.30	1.30	70.0	4.7
" 15	24.00	0.00	32,749	1,404	2,167	32,902	00	00	00	247,000	246,000	11.8	98	49	98	49	0.00	0.00	0.00	68.8	4.5
" 16	24.00	0.00	33,180	1,304	1,999	33,070	65	267	332	248,000	246,000	11.6	101	50	98	49	0.20	0.80	1.00	68.2	4.1
" 17	5.20	18.80	6,653	1,304	406	6,653	164	300	464	230,000	227,000	12.0	99	50	90	45	2.47	4.51	6.98	67.8	4.1
" 18	19.13	4.87	21,727	1,304	1,354	21,727	00	00	00	204,000	204,000	17.8	81	81	81	81	0.00	0.00	0.00	65.5	4.1
" 19	23.80	0.20	28,431	1,500	1,579	28,627	98	327	425	216,000	212,000	13.6	90	90	85	85	0.35	1.15	1.50	67.3	3.7
" 20	24.00	0.00	31,915	1,369	1,491	31,784	109	337	446	240,000	236,000	12.1	98	98	94	94	0.34	1.05	1.39	66.8	3.1
" 21	24.00	0.00	32 262	1,336	1,561	32,229	142	338	480	242,000	238.000	12.0	100	100	95	95	0.44	1.05	1.49	66.3	3.2
" 22	23.63	0.37	32,166	1,314	1,620	32,144	00	00	00	245,000	245,000	12.0	98	98	98	98	0.00	0.00	0.00	66.6	3.4
" 23	24.00	0.00	32,423	1,352	1,582	32,461	130	316	440	243,000	240,000	11.9	99	99	96	96	0.40	0.97	1.37	67.2	3.3
" 24	24 00	0.00	32,560	1,420	1,552	32,630	87	327	414	245,000	242,000	11.9	100	100	97	97	0.27	1.00	1 27	63.8	3.0
" 25	18.00	0.00	24,772	1,562	1,221	24,914	00	00	00	249,000	247,000	11.9	99	99	99	99	0.00	0.00	0.00	59.4	2.9
Total	957.38	74.95	1,174,324	.....	82,621	1,217,684	4,794	11,927	16,678	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....	.....	.....	.....	.....	.....	.....	.....	.....	230,721	227,545	15.4	93	56	87	54	0.43	1.03	1.46	64.7	4.4

*Quantities corresponding to refilling precipitation tank after draining.

†Quantities unknown, due to wasting water into sewer.

‡Quantities estimated.

TABLE NO. 2 — *Summary of Average Qualitative*

CALENDAR DAY. 1899.	Lime (Calcium Oxide) in Grains per Gallon.				Suspended Matter.							Nitrogenous Organic Matter.						
		Excess.			Parts per Million.				Percentage Removal.			Parts per Million.				Percentage Removal.		
	Applied in River Water.	Subsided Water.	Sand Effluent.	Polarite Effluent.	River Water.	Subsided Water.	Sand Effluent.	Polarite Effluent.	Subsiding Tank.	Sand Filter.	Polarite Filter.	River Water.	Subsided Water.	Sand Effluent.	Polarite Effluent.	Subsiding Tank.	Sand Filter.	Polarite Filter.
March 13	5.9	5.4	5.0	4.5	245	15	0	0	93.9	100	100	.268	.058	.056	.054	78.4	78.2	79.0
" 14	6.0	4.3	4.4	4.1	233	17	0	0	92.7	100	100	.246	.068			72.4		
" 15	6.7	5.0	4.8	4.7	227	13	0	0	94.3	100	100	.238	.070	.044	.044	70.6	80.9	80.9
" 16	5.3	4.0	3.9	3.9	210	23	0	0	89.0	100	100	.224	.058			74.1		
" 17	5.4	3.7	3.7	3.6	200	14	0	0	93.0	100	100	.190	.048	.036	.036	74.7	80.7	80.7
" 18	4.7	3.2	2.9	2.8	174	15	0	0	91.4	100	100	.184	.054			70.6		
" 19	3.9	2.2	2.2	2.2	387	44	0	0	88.6	100	100	.312	.078	.050	.044	75.0	85.3	87.1
" 20	3.3	2.6	2.3	2.0	469	47	1	0	90.0	99.8	100	.368	.086			76.6		
" 21	4.0	2.9	2.7	2.6	410	50	1	0	87.8	99.8	100	.314	.080	.042	.032	74.5	86.6	89.8
" 22	3.5	2.9	2.5	2.4	461	47	0	0	89.8	100	100	.314	.072			77.1		
" 23	3.1	2.9	2.2	2.0	438	75	4	0	82.9	99.1	100	.374	.110	.060	.050	70 6	81.2	84.4
" 24	3.6	3.1	2.3	2.2	277	62	6	1	77.6	97.8	99.6	.264	.098			62.9		
" 25	3.4	2.6	2.3	2.2	235	56	2	0	76.2	99.1	100	.240	.102	.060	.052	57.5	76.3	79.5
" 26	3.4	2.8	2.3	2.2	225	56	1	0	74.7	99.6	100	.266	.104			60.9		
" 27	3.2	2.6	2.1	2.0	213	60	4	1	71.8	98.1	99.5	.260	.116	.088	.068	55.4	75 8	81.3
" 28	3.2	2.4	2.0	1.9	509	88	6	1	82.7	98.8	99.8	.466	.160			65.7		
" 29	3.7	2.9	2.3	2.1	394	70	4	1	82.2	99.0	99.7	.320	.136	.084	.076	57.5	82.0	83.7
" 30	3.8	2.9	2.3	2.4	944	99	14	7	89.5	98.5	99.3	.616	.146			76.3		
" 31	4.5	2.6	2.1	2.0	825	104	37	21	87.4	95.5	97.5	.494	.140	.080	.070	71.7	80.9	83.3
April 1	6.4	5.7	5 1	4.0	877	47	1	0	94.6	99.9	100	.346	.092			73.4		
" 2	6.1	4.9	3.1	2.8	432	44	4	2	89.8	99.1	99.5	.342	.090	.046	.052	73.7	84.8	82.8
" 3	5.3	4.7	1.1	1.0	269	30	1	1	88.8	99.6	99.6	.262	.070			73.2		
" 4	5.4	4.8	2.5	2.2	260	30	1	0	88.5	99.6	100	.248	.072	.046	.044	71.0	81.4	82.2
" 5	5.3	4.5	0.1	0.2	277	32	1	1	88.5	99.6	99.6	.246	.076			69.1		
" 6	4.9	4.0	0.2	0.5	183	31	1	0	83.0	99.5	100	.186	.068	.042	.040	63.4	77.4	78.5
" 7	4.8	3.6	0.1	0.0	160	22	0	0	86.3	100	100	.186	.060			67.8		
" 8	5.1	3.1	0.0	0.0	195	25	1	1	87.2	99.5	99.5	.204	.062	.038	.044	69.6	82.8	80.1
" 9	4.6	3.0	0.0	0.1	241	29	4	3	88.0	98.3	98.8	.238	.074			69.0		
" 10	4.2	3.0	0.2	0.3	280	37	3	0	86.8	98.9	100	.146	.054	.042	.038	63.0	72.9	75.5
" 11	4.2	3.0	0.0	0.0	216	29	2	0	86.6	99.1	100	.164	.066			59.5		
" 12	4.3	2.9	2.6	1.2	184	24	1	2	87.0	99.5	98.9	.178	.060	.082	.054	66.2	52.3	68.6
" 13	4.8	3.4	2.9	0 / 5.3†	154	21	0	0	86.4	100	100	.166	.072			56.6		
" 14	4.7	3.0	2.7	0 / 4.7†	86	14	0	0	83.7	100	100	.122	.042			65.6		
" 15	4.5	3.0	2.8	0 / 4.8†	104	15	0	0	85.6	100	100	.124	.048	.026	.022	61.3	78.9	82.1
" 16	4.1	2.7	2.7	0 / 4.4†	102	16	0	0	84.3	100	100	.124	.052			58.0		
" 17	4.1	3.1	2.5	0.3	88	10	0	0	88.7	100	100	.134	.050	.....	.....	62.8	.....	.....
" 18	4.1	2.8	2.3	0.1	98	16	0	0	83.7	100	100	.156	.064	.046	.052	58.9	69 1	65.1
" 19	3.7	2.2	1.9	0.2	83	18	0	0	78.3	100	100	.142	.076			66.4		
" 20	3.1	1.7	1.5	0.1	65	16	0	0	75.4	100	100	.118	.062	.044	.040	47.4	63.9	67.2
" 21	3.2	1.7	1.2	0 / 2.9†	65	14	0	0	78.5	100	100	.122	.068			44.4		
" 22	3.4	1.9	1.8	0 / 3.2†	66	17	0	0	74.2	100	100	.092	.078	.034	.034	15.2	68.2	68.2
" 23	3.3	1.8	1.5	0 / 3.4†	58	14	0	0	75.9	100	100	.122	.050			59.0		
" 24	3.0	1.4	1.3	0 / 3.0†	60	24	0	0	60.0	100	100	.130	.070	.038	.038	46.2	68.8	68.8
" 25	2.9	1.3	1.1	0 / 2.6†	55	15	0	0	72.8	100	100	.114	.048			57.9		
Average	4.3	3.1	2.2	1.5	273	35	2	1	87.2	99.3	99.6	.236	.078	.051	.047	66.9	78.4	80.1

†Total alkalinity.

Results of Operations corresponding to Calendar Days.

Carbonaceous Organic Matter.							Bacteria.						
Parts per Million.				Percentage Removal.			Per Cubic Centimeter.				Percentage Removal.		
River Water.	Subsided Water.	Sand Effluent.	Polarite Effluent.	Subsiding Tank.	Sand Filter.	Polarite Effluent.	River Water.	Subsided Water.	Sand Effluent.	Polarite Effluent.	Subsiding Tank.	Sand Filter.	Polarite Filter.
6.0	2.6	1.6	1.3	56.7	72.2	77.2	28,600	400	30	18	98.6	99.9	99.9
5.5	1.8			67.3			23,900	450	16	20	98.1	99.9	99.9
5.6	1.5	1.2	1.2	73.2	77.4	77.4	25,800	350	6	4	98.6	99.9	99.9
5.0	1.5			70.0			19,900	210	4	7	98.9	99.9	99.9
4.8	1.3	1.0	0.9	72.9	79.4	81.4	23,500	275	5	3	98.8	99.9	99.9
4.9	1.0			79.6			22,800	325	1	1	98.6	99.9	99.9
7.1	1.7	1.3	1.3	76.1	81.4	81.4	37,100	1,900	70	37	94.9	99.8	99.9
6.9	2.1			69.6			55,000	2,500	325	275	95.5	99.4	99.5
7.1	2.3	1.3	1.3	67.6	82.0	82.0	31,400	1,400	190	130	95.5	99.4	99.6
7.4	2.2			70.3			27,400	1,900	300	200	93.1	98.9	99.3
7.2	2.8	1.7	1.9	61.1	73.8	70.7	37,400	3,100	500	375	91.7	98.7	99.0
5.9	3.1			47.5			29,500	2,400	350	225	91.9	98.8	99.2
5.0	2.4	1.5	1.6	52.0	71.7	69.8	37,700	2,900	200	190	92.3	99.5	99.5
5.7	3.1			45.6			36,300	2,700	350	180	92.6	99.0	99.5
6.4	3.1	1.8	1.9	51.6	75.6	74.3	34,600	4,700	550	350	86.4	98.6	99.0
8.4	3.4			59.5			36,000	3,700	375	400	89.7	99.0	98.7
8.7	3.3	2.0	1.9	62.0	82.6	83.5	35,900	3,100	450	400	91.4	98.5	98.7
14.3	3.3			76.9			34,800	2,000	1,100	550	94.3	96.8	98.4
12.8	3.4	2.2	1.9	73.4	83.1	85.4	37,400	4,300	1,800	1,300	88.5	95.2	96.5
13.4	2.5			81.3			39,900	1,300	230	180	96.7	99.4	99.5
8.4	2.6	1.7	1.7	69.0	76.4	76.4	38,500	1,100	170	170	97.1	99.6	99.6
6.0	2.1			65.0			36,100	1,000	150	150	97.2	99.6	99.6
6.4	1.8	1.5	1.3	71.9	77.1	80.2	25,800	1,900	100	100	92.6	99.6	99.6
6.7	1.8			78.1			22,300	700	190	120	96.9	99.1	99.5
5.2	1.8	1.4	1.4	65.4	70.6	70.6	16,500	1,000	160	170	93.9	99.0	99.0
4.3	1.6			62.8			17,700	700	175	150	96.0	99.0	99.2
5.4	1.7	1.7	1.5	68.5	70.1	73.6	24,400	600	325	275	96.5	98.7	98.9
6.0	1.8			70.0			18,200	700	350	300	96.2	98.1	98.3
5.9	1.7	1.4	1.2	71.2	74.1	77.7	24,900	1,500	550	550	94.0	97 8	97.8
4.9	1.6			67.3			26,600	1,200	650	600	95.5	97.6	97.7
3.8	1.4	1.1	1.1	63.2	69.5	69.5	18,500	500	150	275	97.3	99.2	98.5
3.4	1.2			64.7			14,500	550	17	275	96.2	99.9	98.1
2.9	1.3			55.2			15,000	300	18	300	98.0	99.9	98.0
3.3	1.3	0.8	0.9	60.6	73.3	70.0	14,100	375	4	350	97.3	99.9	97.5
2.9	1.3			55.2			12,300	300	8	325	97.6	99.9	97.4
3.7	1.3	.....	.....	64.9	.....	.....	15,300	300	34	1,000	98.5	99.8	93.5
5.1	1.7	1.8	0.7	66.7	58.2	83.7	10,300	375	12	750	96.4	99.9	92.7
3.6	1 2			66.7			7,800	275	37	900	96.5	99.5	88.5
2.8	1.7	0.8	0.8	39.3	71.4	71.4	5,400	180	600	1,700	96.7	88.9	68.5
2.8	1.6			42.8			5,000	190	95	1,200	96.2	98.1	76.0
2.9	1.2	0.9	0.8	58.6	67.9	71.4	7,000	275	110	1,000	96.1	98.4	85.7
2.7	1.1			59.3			5,400	300	27	950	94.4	99.5	82.4
2.7	1.5	1.0	0.9	44.4	61.5	65.4	8,300	1,400	80	850	83.1	99.0	89.7
2.5	1.2			52.0			5,200	300	40	1,100	94.2	99.2	78.8
5.7	2.0	1.4	1.3	64.9	75.5	77.2	23,800	1,300	250	425	94.5	99.0	98.2

TABLE NO. 3—*Record of the Agitations and Washing—Sand Filter.*

Number.	Date. 1899.	Hour.	Quantities of Effluent. Cubic Feet.		Wash Water. Cubic Feet.			Percentage of Effluent since last Wash.			Estimated parts of applied Suspended Matter.	Loss of Head. Feet.		Periods of Time. Min.	
			Agitation since Last Agitation or Wash.	Washing since Last Wash.	Unfiltered.	Filtered.	Total.	Unfiltered.	Filtered.	Total.		Before.	After.	Agitation.	Wash.
Agitation 1-a..	Mar. 14	3:23 PM	22,565	.....	....	....	....	....	....	....	....	8.0	1.5	12	....
Agitation 1-b..	" 14	9:34 PM	6,293	.....	....	....	....	....	....	....	....	9.7	6.0	3	....
Agitation 1-c..	" 14	12:00 PM	2,574	.....	....	....	....	....	....	....	....	11.4	9.7	3	....
Wash 1.....	" 15	2:30 AM	.....	33,156	218	213	431	0.66	0.64	1.30	17	8.9	3.5	....	33
Agitation 2-a..	" 15	12:05 PM	10,067	.....	....	....	....	....	....	....	....	8.0	3.8	5	....
Agitation 2-b..	" 15	9:49 PM	6,058	.....	....	....	....	....	....	....	....	8.1	6.1	1	....
Agitation 2-c..	" 16	1:47 AM	4,172	.....	....	....	....	....	....	....	....	7.4	6.4	1	....
Agitation 2-d..	" 16	3:47 AM	2,234	.....	....	....	....	....	....	....	....	7.3	5.7	1	....
Agitation 2-e..	" 16	6:07 AM	2,496	.....	....	....	....	....	....	....	....	7.6	7.1	1	....
Wash 2.....	" 16	9:05 AM	.....	28,263	218	218	436	0.77	0.77	1.54	13	7.6	2.3	....	60
Agitation 3-a..	" 16	5:28 PM	6,510	.....	....	....	....	....	....	....	....	11.4	3.4	14	....
Agitation 3-b..	" 16	11:52 PM	8,193	.....	....	....	....	....	....	....	....	7.1	4.2	1	....
Agitation 3-c..	" 17	2:40 AM	3,688	.....	....	....	....	....	....	....	....	6.0	4.8	1	....
Agitation 3-d..	" 17	3:43 AM	1,309	.....	....	....	....	....	....	....	....	5.6	5 5	1	....
Agitation 3-e..	" 17	5:05 AM	1,781	.....	....	....	....	....	....	....	....	6.3	6.0	1	....
Wash 3.....	" 17	6:32 AM	.....	23,425	218	251	469	0.93	1.07	2.00	23	6.0	3.5	....	42
Agitation 4-a..	" 17	3:06 PM	10,108	.....	....	....	....	....	....	....	....	7.3	4.0	9	....
Agitation 4-b..	" 17	10:00 PM	8,809	.....	....	....	....	....	....	....	....	7.8	4.8	1	....
Agitation 4-c..	" 17	11:27 PM	1,882	.....	....	....	....	....	....	....	....	6.0	4.9	1	....
Wash 4.....	" 18	12:30 AM	.....	22,211	218	278	496	0.98	1.25	2.23	18	5.5	3.5	....	30
Agitation 5-a..	" 18	7:10 AM	8,423	.....	....	....	....	....	....	....	....	7.2	3.8	1	....
Agitation 5-b..	" 18	2:40 PM	8,150	.....	....	....	....	....	....	....	....	5.7	5.0	2	....
Agitation 5-c..	" 18	7:06 PM	3,484	.....	....	....	....	....	....	....	....	7.6	6.5	1	....
Agitation 5-d..	" 18	8:38 PM	2,073	.....	....	....	....	....	....	....	....	6.8	5.9	2	....
Wash 5.....	" 18	9:19 PM	.....	22,765	218	262	480	0.96	1.15	2.11	14	6.0	2.7	....	18
Agitation 6-a..	" 19	3:11 AM	7,620	.....	....	....	....	....	....	....	....	7.4	4.5	1	....
Agitation 6-b..	" 19	12:04 PM	12,204	.....	....	....	....	....	....	....	....	6.7	4.9	1	....
Agitation 6-c..	" 19	2:00 PM	2,605	.....	....	....	....	....	....	....	....	6.0	5.1	7	....
Agitation 6-d..	" 19	5:16 PM	4,292	.....	....	....	....	....	....	....	....	6.8	2.3	4	....
Agitation 6-e..	" 19	9:01 PM	4,716	.....	....	....	....	....	....	....	....	7.4	6.4	1	....
Wash 6.....	" 19	10:00 PM	.....	32,777	218	267	485	0.67	0.81	1.48	18	7.0	2.5	....	34
Agitation 7-a..	" 20	6:30 AM	11,025	.....	....	....	....	....	....	....	....	6.2	4.2	1	....
Agitation 7-b..	" 20	10:30 AM	5,701	.....	....	....	....	....	....	....	....	5.6	3.5	3	....
Agitation 7-c..	" 20	2:43 PM	4,395	.....	....	....	....	....	....	....	....	7.9	5.3	3	....
Agitation 7-d..	" 20	4:11 PM	1,674	.....	....	....	....	....	....	....	....	6.9	5.2	3	....
Wash 7.....	" 20	4:45 PM	.....	23,496	76	306	382	0.32	1.31	1.63	51	7.4	2.8	....	34
Agitation 8-a..	" 21	3:42 AM	14,399	.....	....	....	....	....	....	....	....	7.4	5.4	1	....
Agitation 8-b..	" 21	6:31 AM	3,888	.....	....	....	....	....	....	....	....	7.0	6.2	2	....
Agitation 8-c..	" 21	9:58 AM	4,003	.....	....	....	....	....	....	....	....	8.1	7.2	3	....
Wash 8.....	" 21	2:43 PM	.....	26,663	76	289	365	0.29	1.08	1.37	44	8.5	3.4	....	42
Agitation 9-a..	" 22	3:13 AM	15,653	.....	....	....	....	....	....	....	....	6.8	5.2	2	....
Agitation 9-b..	" 22	9:00 AM	7,581	.....	....	....	....	....	....	....	....	8.3	3.0	4	....
Agitation 9-c..	" 22	11:25 AM	2,806	.....	....	....	....	....	....	....	....	7.7	3.9	2	....
Wash 9.....	" 22	1:30 PM	.....	28,058	103	272	375	0.37	0.97	1.34	50	8.1	2.6	....	32
Agitation 10-a.	" 23	3:08 AM	17,205	.....	....	....	....	....	....	....	....	6.8	4.8	2	....
Agitation 10-b.	" 23	5:10 AM	2,781	.....	....	....	....	....	....	....	....	6.7	5.0	3	....
Wash 10.....	" 23	6:55 AM	.....	22,240	65	278	343	0.29	1.25	1.54	47	6.5	1.7	....	35
Agitation 11-a.	" 23	6:39 PM	14,583	.....	....	....	....	....	....	....	....	6.8	1.8	1	....
Wash 11.....	" 23	8:10 PM	.....	16,474	218	234	452	1.32	1.43	2.75	65	5.9	3.5	....	30
Agitation 12-a.	" 24	6:16 AM	12,412	.....	....	....	....	....	....	....	....	6.8	5.6	3	....
Wash 12.....	" 24	8:00 AM	.....	14,665	87	273	360	0.59	1.86	2.45	77	6.5	3.8	....	28
Agitation 13-a.	" 24	7:33 PM	11,208	.....	....	....	....	....	....	....	....	7.6	6.5	3	....
Agitation 13-b.	" 24	10:24 PM	3,829	.....	....	....	....	....	....	....	....	6.7	6.4	6	....
Wash 13.....	" 25	12:39 AM	.....	17,884	93	305	398	0.52	1.70	2.22	68	6.7	3.6	....	45
Agitation 14-a	" 25	11:12 AM	13,366	.....	....	....	....	....	....	....	....	7.3	5.9	6	....
Agitation 14-b.	" 25	1:00 PM	2,068	.....	....	....	....	....	....	....	....	5.9	3.4	2	....
Agitation 14-c.	" 25	7:18 PM	6,736	.....	....	....	....	....	....	....	....	7.6	5.8	1	....
Wash 14.....	" 25	7:25 PM	.....	22,343	131	251	382	0.59	1.13	1.72	54	6.2	3.3	....	35

TABLE No. 3—*Record of the Agitations and Washing—Sand Filter*—(Continued).

Number.	Date. 1899.	Hour.	Quantities of Effluent. Cubic Feet.		Wash Water. Cubic Feet.			Percentage of Effluent since last Wash.			Estimated parts of applied Suspended Matter.	Loss of Head. Feet.		Periods of Time.		
			Agitation since Last Agitation or Wash.	Washing since Last Wash.	Unfiltered.	Filtered.	Total.	Unfiltered.	Filtered.	Total.		Before.	After.	Min. Agitation.	Min. Wash.	Hrs. Service.
Agitation 15-a.	Mar. 26	4:35 AM	11,963	.....	....	....	....	....	....	....	....	6.1	5.1	2	....	.....
Agitation 15-b.	" 26	9:30 AM	6,558	.....	....	....	....	....	....	....	....	7.3	6.3	2	....	.....
Agitation 15-c.	" 26	10.43 AM	1,495	.....	....	....	....	....	....	....	....	7.0	5.4	14	....	.....
Wash 15.....	" 26	12:11 PM	.....	21,663	87	273	360	0.40	1.26	1.66	55	6.6	2.6	....	42	16.87
Agitation 16-a.	" 26	9:49 PM	11,900	.....	....	....	....	....	....	....	....	6.8	4.7	1	....	.....
Agitation 16-b.	" 27	2:10 AM	5,987	.....	....	....	....	....	....	....	....	6.0	5.0	2	....	.....
Agitation 16-c.	" 27	4:19 AM	2,936	.....	....	....	....	....	....	....	....	6.4	5.4	7	....	.....
Wash 16.....	" 27	5:55 AM	.....	22,882	60	223	283	0.26	0.98	1.24	56	6.5	3.1	....	35	17.62
Agitation 17-a.	" 27	2:15 PM	10,048	.....	....	....	....	....	....	....	....	6.6	3.9	9	....	.....
Agitation 17-b.	" 27	6:00 PM	4,548	.....	....	....	....	....	....	....	....	8.1	3.1	5	....	.....
Wash 17.....	" 27	7:09 PM	.....	16,047	87	272	359	0.54	1.69	2.23	65	5.6	3.6	....	38	13.00
Agitation 18-a.	" 28	3:18 AM	10,377	.....	....	....	....	....	....	....	....	5.9	5.5	1	....	.....
Agitation 18-b.	" 28	5:10 AM	2,496	.....	....	....	....	....	....	....	....	6.3	5.9	1	....	.....
Wash 18.....	" 28	6:15 AM	.....	14,344	60	256	316	0.42	1.78	2.20	60	6.7	3.2	....	30	10.97
Agitation 19-a.	" 28	4:15 PM	12,144	.....	....	....	....	....	....	....	....	7.3	3.5	3	....	.....
Agitation 19-b.	" 28	7:25 PM	4,010	.....	....	....	....	....	....	....	....	6.1	5.5	1	....	.....
Agitation 19-c.	" 28	10:05 PM	3,700	.....	....	....	....	....	....	....	....	7.1	6.9	1	....	.....
Wash 19.....	" 28	11:38 PM	.....	21,942	76	240	316	0.35	1.10	1.45	80	7.1	3.4	....	40	17.55
Agitation 20-a.	" 29	10:40 AM	14,363	.....	....	....	....	....	....	....	....	8.6	3.0	13	....	.....
Agitation 20-b.	" 29	2:34 PM	4,069	.....	....	....	....	....	....	....	....	9.4	5.3	2	....	.....
Wash 20.....	" 29	4:26 PM	.....	20,017	98	273	371	0.49	1.36	1.85	91	6.5	3.5	....	49	16.08
Agitation 21-a.	" 30	2:05 AM	12,225	.....	....	....	....	....	....	....	....	7.3	6.0	2	....	.....
Agitation 21-b.	" 30	3:43 AM	2,200	.....	....	....	....	....	....	....	....	6.5	6.2	1	....	.....
Wash 21.....	" 30	5:32 AM	.....	16,837	87	273	360	0.52	1.62	2.14	70	7.0	3.5	....	28	12.75
Agitation 22-a.	" 30	2:23 PM	11,083	.....	....	....	....	....	....	....	....	8.0	4.2	7	....	.....
Agitation 22-b.	" 30	8:46 PM	7,947	.....	....	....	....	....	....	....	....	7.2	6.3	2	....	.....
Agitation 22-c.	" 30	11:23 PM	3,454	.....	....	....	....	....	....	....	....	7.4	6.7	1	....	.....
Wash 22.....	" 31	1:14 AM	.....	24,943	87	267	354	0.35	1.07	1.42	92	7.8	3.3	....	23	20,12
Agitation 23-a.	" 31	2:00 PM	13,855	.....	....	....	....	....	....	....	....	9.5	5.5	14	....	.....
Agitation 23-b	" 31	7:12 PM	6,015	.....	....	....	....	....	....	....	....	7.7	5.8	3	....	.....
Wash 23.....	" 31	8:52 PM	.....	21,635	120	273	393	0.55	1.26	1.81	106	7.0	2.7	....	33	19.27
Wash 24.....	April 2	5:00 AM	.....	13,405	00	349	349	0.00	2.61	2.61	91	....	3.7	....	55	12.18
Agitation 25-a.	" 3	2:20 AM	26,106	.....	....	....	....	....	....	....	....	7.4	4.7	1	....	.....
Agitation 25-b.	" 3	5:34 AM	4,236	.....	....	....	....	....	....	....	....	7.4	6.1	1	....	.....
Wash 25.....	" 3	10:42 AM	.....	36,820	103	338	441	0.28	0.92	1.20	45	8.6	1.7	....	42	24.50
Agitation 26-a.	" 3	4:45 PM	6,924	.....	....	....	....	....	....	....	....	8.7	3.9	5	....	.....
Agitation 26-b.	" 4	2:23 AM	13,029	.....	....	....	....	....	....	....	....	8.4	4.9	3	....	.....
Agitation 26-c.	" 4	10:29 AM	10,987	.....	....	....	....	....	....	....	....	8.4	4.5	4	....	.....
Agitation 26-d.	" 4	4:00 PM	7,153	.....	....	....	....	....	....	....	....	8.2	5.2	5	....	.....
Wash 26.....	" 4	5:30 PM	.....	39,767	98	327	425	0.25	0.82	1.07	30	5.4	3.0	....	33	30.67
Agitation 27-a.	" 5	5:40 AM	14,311	.....	....	....	....	....	....	....	....	7.0	3.3	3	....	.....
Agitation 27-b.	" 5	2:27 PM	12,333	.....	....	....	....	....	....	....	....	6.9	3.1	6	....	.....
Agitation 27-c.	" 5	9:39 PM	9,594	.....	....	....	....	....	....	....	....	6.3	6.2	2	....	.....
Agitation 27-d.	" 6	5:06 AM	10,370	.....	....	....	....	....	....	....	....	7.7	5.3	4	....	.....
Wash 27.....	" 6	10:25 AM	.....	53,851	98	338	436	0.18	0.63	0.81	31	6.9	5.2	....	59	34.10
Agitation 28-a.	" 7	9:17 AM	28,788	.....	....	....	....	....	....	....	....	7.5	3.4	3	....	.....
Agitation 28-b.	" 8	5:22 AM	27,583	.....	....	....	....	....	....	....	....	7.3	5.3	3	....	.....
Agitation 28-c.	" 8	4:35 PM	15,457	.....	....	....	....	....	....	....	....	7.1	3.4	5	....	.....
Wash 28.....	" 8	11:35 PM	.....	81,023	152	332	484	0.19	0.41	0.60	25	7.0	2.3	....	55	60.27
Agitation 29-a.	" 11	1:40 AM	68,693	.....	....	....	....	....	....	....	....	7.4	4.7	4	....	.....
Wash 29.....	" 11	10:55 AM	.....	81,279	98	327	425	0.12	0.40	0.52	30	8.6	2.3	....	31	58 94
Wash 30.....	" 12	8:57 AM	.....	29,622	120	338	458	0.41	1.14	1.55	33	4.7	2.9	....	18	21.80
Agitation 31-a.	" 13	9:05 AM	20,132	.....	....	....	....	....	....	....	....	7.6	3.6	3	....	.....
Agitation 31-b.	" 13	2:07 PM	6,890	.....	....	....	....	....	....	....	....	5.9	4.4	3	....	.....
Wash 31.....	" 13	9:38 PM	.....	36,562	120	278	398	0.33	0.76	1.09	23	8.6	2.5	....	30	27.40
Agitation 32-a.	" 14	5:30 AM	10,353	.....	....	....	....	....	....	....	....	5.4	2.8	1	....	.....
Agitation 32-b.	" 14	2:04 PM	11,713	.....	....	....	....	....	....	....	....	8.0	4.4	3	....	.....
Wash 32.....	" 14	7:40 PM	.....	25,897	....	338	338	....	1.30	1.30	16	3.8	2.2	....	45	22.95

TABLE No. 3—*Record of the Agitations and Washing—Sand Filter*—(Concluded).

Number.	Date. 1899.	Hour.	Quantities of Effluent. Cubic Feet.		Wash Water. Cubic Feet.			Percentage of Effluent since last Wash.			Loss of Head. Feet.		Periods of Time.		
			Agitation since Last Agitation or Wash.	Washing since Last Wash.	Unfiltered.	Filtered.	Total.	Unfiltered.	Filtered.	Total.	Estimated parts of applied Suspended Matter.	Before.	After.	Min. Agitation.	Min. Wash.	Hrs. Service.
Agitation 33-a.	April 15	11:00 AM	18,064									7.2	2.6	5		
Agitation 33-b.	" 15	7:05 PM	10,843									8.6	3.7	1		
Agitation 33-c.	" 15	10:04 PM	3,970									5.6	4.1	1		
Agitation 33-d.	" 15	11:52 PM	2,501									5.5	4.2	1		
Agitation 33-e.	" 16	1:57 AM	2,974									5.1	4.5	1		
Wash 33	" 16	4:03 AM		41,250	65	267	332	0.16	0.65	0.81	12	7.0	1.8		27	28.80
Agitation 34-a.	" 16	12:00 M	10,900									7.8	3.0	5		
Agitation 34-b.	" 16	6:17 PM	9,014									7.0	3.2	2		
Agitation 34-c.	" 16	9:44 PM	4,507									6.0	3.9	1		
Agitation 34-d.	" 17	12:42 AM	4,047									6.4	4.0	1		
Agitation 34-e.	" 17	2:33 AM	2,517									5.3	3.9	2		
Wash 34	" 17	4:56 AM		34,122	65	267	332	0.19	0.78	0.97	18	6.1			26	24.70
Agitation 35-a.	" 18	10:06 PM	20,207									9.9	4.8	3		
Agitation 35-b.	" 19	5:01 AM	7,631									9.6	6.0	3		
Agitation 35-c.	19	11:30 AM	7,022									10.0	4.4	2		
Wash 35	" 19	3:00 PM		39,107	98	327	425	0.25	0.83	1.08	12	11.2	2.2		30	34.93
Agitation 36-a.	" 20	2:09 AM	14,580									6.8	3.8	1		
Agitation 36-b.	" 20	9:52 AM	10,445									8.0	4.3	3		
Wash 36	" 20	2:30 PM		30,930	109	337	446	0.35	1.09	1.44	17	6.1	2.0		25	23.40
Agitation 37-a.	" 21	3:18 AM	17,205									6.2	3.0	2		
Agitation 37-b.	" 21	8:24 AM	6,929									6.2	3.4	2		
Agitation 37-c.	" 21	1:52 PM	7,230									6.9	3.5	3		
Wash 37	" 21	3:45 PM		33,771	142	338	480	0.42	1.00	1.42	14	6.0	3.3		26	25.27
Agitation 38-a.	" 22	4:10 AM	16,304									6.7	3.3	1		
Agitation 38-b.	" 22	9:00 AM	6,653									6.5	3.1	3		
Agitation 38-c.	" 22	1:20 PM	5,954									5.8	3.7	3		
Agitation 38-d.	" 22	6:49 PM	7,111									9.6	4.4	1		
Agitation 38-e.	" 22	9:10 PM	3,226									6.4	4.8	2		
Agitation 38-f.	" 22	11:41 PM	3,589									5.7	4.4	2		
Wash 38	" 23	1:25 AM		45,145	130	316	446	0.29	0.70	0.99	17	6.0	1.6		28	33.33
Agitation 39-a.	" 23	1:12 PM	15,829									5.8	2.7	2		
Agitation 39-b.	" 23	9:01 PM	10,452									8.3	3.8	2		
Agitation 39-c.	" 24	1:17 AM	5,948									6.0	3.3	1		
Agitation 39-d.	" 24	5:03 AM	5,250									7.0	3.7	1		
Wash 39	" 24	9:40 AM		43,836	87	327	414	0.20	0.74	0.94	15	6.5	1.9		25	32.39
Agitation 40-a.	" 25	1:36 AM	21,488									6.2	2.8	1		
Agitation 40-b.	" 25	10:15 AM	11,920									6.1	3.2	2		

TABLE NO. 4—*Record of the Agitations and Washes—Polarite Filter.*

Number.	Date. 1899.	Hour.	Quantities of Effluent. Cubic Feet.		Wash Water. Cubic Feet.			Percentage of Effluent since last Wash.			Estimated parts of applied Suspended Matter.	Loss of Head. Feet.		Periods of Time. Min.		Hrs.
			Agitation since Last Agitation or Wash.	Washing since Last Wash.	Unfiltered.	Filtered.	Total.	Unfiltered.	Filtered.	Total.		Before.	After.	Agitation.	Wash.	Service.
Agitation 1-a..	Mar. 27	4:19 AM	376,906	.....	....	....	....	...	....	....	....	*	3.6	7	....	.....
Agitation 1-b..	" 29	4:59 PM	74,409	.....	....	....	....	....	....	....	....	*	4.1	1	....	.....
Agitation 1-c..	" 30	3:52 PM	29,295	.....	....	....	....	....	....	....	....	*	4.3	1	....	.....
Wash 1.....	" 31	1:37 AM	.....	493,095	131	849	480	0.03	0.07	0.10	2	*	2.3	....	30	†
Wash 2	April 2	10:16 AM	.....	40,841	163	354	517	0.40	0.87	1.27	20	*	1.9	....	53	‡

* Loss of head not indicated by gage. †16 days—15.8 hours. ‡12.33 hours.

TABLE NO. 5—*Results of Special Analyses, showing the amount of Suspended Matter and the Number of Bacteria in the Effluent from Different Taps on the Precipitation Tank, corresponding to Different Periods of Subsidence.*

Collected.		Parts per Million of Suspended Matter.						Bacteria per Cubic Centimeter.					
Date. 1899.	Hour.	River Water.	Effluent at Tap Number					River Water.	Effluent at Tap Number				
			1	2	3	4	Outlet.		1	2	3	4	Outlet.
March 23..	5 PM	438	175	158	114	91	72	37,400	6,100	6,800	4,100	2,900	3,200
" 24..	5 PM	277	118	83	81	61	61	29,500	3,500	2,100	2,200	1,200	2,400
" 27..	5 PM	213	98	91	76	65	62	34,600	2,800	2,200	2,800	1,800	3.800
" 30..	3 PM	944	142	124	114	86	91	34,800	11,100	7,900	5,500	2,700	3,300
April 2..	4 PM	432	158	91	65	55	38	38,500	1,600	1,100	1,100	600	800
" 4..	5 PM	260	81	68	57	31	29	25,800	800	500	500	250	3,800
" 6..	3 PM	183	68	51	43	37	33	16,500	1,500	1,100	900	850	650
" 8..	3 PM	195	61	34	31	29	16	24,400	900	400	300	200	600
" 10..	3 PM	280	72	63	37	32	34	24,900	2,500	1,600	850	850	1,000
" 13..	3 PM	154	61	65	49	37	27	14,500	1,000	800	650	850	900
" 15..	3 PM	104	45	40	40	16	13	14,100	500	550	450	275	375
" 18..	4 PM	123	39	37	33	27	34	10,300	1,400	650	800	750	500
" 20..	4 PM	98	28	26	28	18	25	5,400	500	400	375	230	210
" 22	3 PM	91	20	18	16	15	17	7,000	425	550	400	300	230
" 24..	3 PM	80	30	26	18	15	22	8,300	7,000	7,200	2,000	650	2,100
Average ..	.....	258	80	65	53	41	38	21,700	2,800	2,300	1,500	950	1,600

TABLE NO. 6.—*Results of Chemical and Bacterial Analyses of the Effluent of the Precipitation Tank.*

[Chemical Results expressed in Parts per Million.]

DATE. 1899.	HOUR. A	B	C	Oxygen Consumed.	NITROGEN AS Albuminoid Ammonia.	Free Ammonia.	CAUSTIC (CaO) ALKALINITY. A	B	C	Average.	Total Residue on Evaporation.	SUSPENDED MATTER. A	B	C	Average.	BACTERIA PER CUBIC CENTIMETER A	B	C	Average.
	PM	PM	AM																
Mar. 13-14	4	12	8	2.6	.058	.022	90	90	98	93	169	25	10	10	15	300	140	750	40
" 14-15	4	12	8	1.8	.068	.020	81	69	74	74	187	11	23	17	17	550	550	300	45
" 15-16	4	12	8	1.5	.070	.018	87	84	85	85	155	13	10	16	13	375	325	400	3
" 16-17	4	12	8	1.5	.058	.016	69	73	64	69	167	25	20	25	23	210	160	250	2
" 17-18	4	12	8	1.3	.048	.010	58	66	69	64	159	12	13	16	14	325	180	325	2
" 18-19	4	12	8	1.0	.054	.016	57	56	53	55	124	18	13	13	15	400	150	425	2
" 19-20	4	12	8	1.7	.078	.014	34	41	36	37	157	81	23	28	44	700	900	4,000	1,8
" 20-21	4	12	8	2.1	.086	.008	42	45	45	44	178	50	44	46	47	2,500	2,300	2,600	2,4
" 21-22	4	12	8	2.3	.080	.008	39	58	49	49	173	37	32	81	50	1,800	500	1,800	1,4
" 22-23	4	12	9	2.2	.072	.008	50	50	50	50	157	37	48	57	47	800	1,800	3,200	1,9
" 23-24	4	12	11	2.8	.110	.012	46	48	53	49	175	72	83	70	75	3,200	3,600	2,800	3,1
" 24-25	4	12	8	3.1	.098	.004	61	42	52	53	181	61	72	52	62	2,400	2,300	2,400	2,4
" 25-26	4	12	8	2.4	.102	.008	42	45	46	44	167	57	53	57	56	2,400	2,200	4,000	2,8
" 26-27	4	12	8	3.1	.104	.010	48	48	48	48	175	49	52	68	56	3,000	1,700	3,400	2,7
" 27-28	4	12	8	3.1	.116	.012	43	46	42	43	179	62	52	65	60	3,800	3,600	6,700	4,7
" 28-29	4	12	8	3.4	.160	.018	32	41	50	41	210	72	102	89	88	4,400	3,500	3,300	3,7
" 29-30	4	12	8	3.3	.136	.014	46	49	56	50	168	81	58	72	70	3,100	2,700	3,400	3,1
" 30-31	4	12	8	3.3	.146	.016	45	48	56	50	224	91	83	124	99	3,300	1,400	1,300	2,0
" 31	4	12	..	3.4	.140	.010	53	56	20	43	215	89	72	150	104	2,900	1,900	8,200	4,3
April 2	7	8	..	2.5	.092	.010	98	95	..	97	193	50	44	..	47	1,500	1,100	.....	1,3
" 2-3	4	12	8	2.6	.090	.014	87	81	81	83	168	38	59	36	44	800	1,000	1,400	1,1
" 3-4	4	12	8	2.1	.070	.010	92	76	73	80	181	29	33	28	30	750	800	1,500	1,0
" 4-5	4	12	8	1.8	.072	.008	81	84	81	82	152	29	18	42	30	3,800	400	1,500	1,9
" 5-6	4	12	8	1.8	.076	.008	81	78	69	76	154	31	33	32	32	750	400	900	7
" 6-7	4	12	8	1.8	.068	.006	70	64	73	69	150	33	30	29	31	650	475	2,000	1,0
" 7-8	4	12	8	1.6	.060	.010	64	63	59	62	147	22	25	20	22	475	750	850	7
" 8-9	4	12	8	1.7	.062	.006	50	50	56	52	140	16	27	31	25	170	550	1,000	6
" 9-10	4	12	8	1.8	.074	.006	49	56	48	51	136	33	25	29	29	550	600	900	7
" 10-11	4	12	8	1.7	.054	.008	59	48	45	51	150	34	32	44	37	1,000	1,000	2,400	1,4
" 11-12	4	12	8	1.6	.066	.008	45	56	52	51	143	40	22	25	29	1,700	750	1,100	1,2
" 12-13	4	12	8	1.4	.060	.002	52	48	50	50	138	30	12	31	24	425	450	700	5
" 13-14	4	12	8	1.2	.072	.008	59	59	59	59	186	27	15	21	21	900	230	550	5
" 14-15	9	12	8	1.3	.042	.008	50	53	53	52	138	13	11	17	14	100	230	350	3
" 15-16	4	12	8	1.3	.048	.006	53	50	50	51	131	13	9	24	15	375	250	500	3
" 16-17	4	12	8	1.3	.052	.004	45	50	..	47	132	17	14	..	16	325	250	.....	2
" 17-18	..	..	8	1.3	.050	.004	53	..	..	53	109	10	..	..	10	230	350	.....	2
" 18-19	4	12	8	1.7	.064	.006	48	45	50	48	106	15	20	12	16	500	400	190	3
" 19-20	4	12	8	1.2	.076	.008	45	36	31	37	127	12	16	25	18	120	160	550	1
" 20-21	4	12	8	1.7	.062	.004	28	28	31	29	130	16	14	20	17	210	140	200	1
" 21-22	4	12	8	1.6	.068	.008	31	28	28	29	123	12	13	15	13	275	160	140	1
" 22-23	4	12	8	1.2	.078	.004	35	32	29	32	128	15	15	20	17	230	170	450	2
" 23-24	4	12	8	1.1	.050	.004	32	28	35	32	120	15	15	13	14	350	250	300	3
" 24-25	4	12	8	1.5	.070	.008	22	27	24	24	160	12	48	16	24	2,100	1,400	850	1,4
" 25	4	..	..	1.2	.048	.006	22	..	..	22	120	15	..	..	15	300	.....	.....	3

TABLE NO. 7—*Results of the Examination of the Effluent of the Sand Filter.*

COLLECTION OF SAMPLES.		Designation.	Rate of Filtration.	Loss of Head. Feet.	PARTS PER MILLION.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 13.....	11.00PM	R	79	2.7	92	0	30
" 14.....	4.00AM	R	76	3.4	94	0	31
" 14.....	12 00M	R	66	5.9	69	0	29
" 14.....	10.20PM	R	80	6.5	76	0	12
" 15.....	3.10AM	W-1	70	2.8	....	1	70
" 15.....	3.23AM	W-2	70	2.8	...	1	48
" 15.....	3.40AM	W-3	70	2.8	....	1	34
" 15.....	4.05AM	W-4	70	2.8	....	1	18
" 15.....	5.00AM	R	78	3.2	74	0	19
" 15.....	7.10PM	R	60	5.9	81	0	3
" 15.....	11.00PM	R	72	5.5	84	0	8
" 16.....	6.00AM	R	83	5.9	84	0	8
" 16.....	10.10AM	W-1	48	3.2	....	0	19
" 16.....	10.17AM	W-2	48	3.2	....	0	20
" 16.....	10.27AM	W-3	48	3.2	....	0	11
" 16.....	10.50AM	W-4	48	4.7	....	0	19
" 16.....	6.00PM	R	95	2.9	70	0	3
" 17.....	1.00AM	R	96	5.1	64	0	2
" 17.....	7.16AM	W-1	92	2.8	67	0	26
" 17.....	7.19AM	W-2	92	2.8	....	0	16
" 17.....	7.28AM	W-3	92	2.8	....	0	6
" 17.....	7.44AM	W-4	92	2.8	....	0	4
" 17.....	3.00PM	R	93	6.0	67	0	12
" 17.....	11.00PM	R	93	5.5	67	0	0
" 18.....	1.06AM	W-1	98	3.4	64	0	5
" 18	1.14AM	W-2	98	3.4	....	0	0
" 18.....	1.25AM	W-3	98	3.4	....	0	1
" 18.....	1.48AM	W-4	98	3.4	....	0	1
" 18	7.00AM	R	88	6.3	56	0	4
" 18.....	3.00PM	R	96	4.8	57	0	0
" 18.....	9.43PM	W-1	88	2.6	....	0	1
" 18.....	9.50PM	W-2	88	2.6	....	0	0
" 18...	10.01PM	W-3	88	2.6	....	0	1
" 18.....	10.24PM	W-4	88	2.6	....	0	3
" 19...	3.00AM	R	90	6.5	48	0	1
" 19.....	11.00AM	R	97	5.6	42	0	1
" 19.....	5.00PM	R	93	6.3	41	0	4
" 19.....	10.39PM	W-1	55	2.5	....	0	30
" 19.....	10.45PM	W-2	55	2.5	....	1	16
" 19.....	11.00PM	W-3	55	2.5	....	0	28
" 19.....	11.17PM	W-4	55	2.5	....	0	35
" 19.....	12.00PM	R	110	3.1	36	0	40
" 20.....	7.00AM	R	104	4.2	38	0	170
" 20.....	2.00PM	R	79	5.9	36	0	300
" 20.....	5.43PM	W-1	126	1.3	....	1	190
" 20.....	5.50PM	W-2	126	1.3	....	1	210

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 20	6.01PM	W-3	126	1.3	....	7	500
" 20	6.24PM	W-4	126	1.3	....	3	325
" 20	8.00PM	R	102	3.8	42	5	220
" 20	11.00PM	R	100	5.0	42	5	450
" 21	1.00AM	R	98	5.7	45	1	425
" 21	3.45AM	A-1	98	5.5	....	5	500
" 21	3.55AM	A-2	98	5.5	....	3	375
" 21	4.00AM	R	98	5.6	42	1	400
" 21	4.06AM	A-3	98	5.6	....	0	400
" 21	4.28AM	A-4	98	5.6	....	2	350
" 21	6.41AM	A-1	93	6.0	....	5	500
" 21	6.49AM	A-2	93	6.0	....	3	300
" 21	7.00AM	R	93	6.0	36	1	300
" 21	7.03AM	A-3	93	6.0	....	3	375
" 21	7.26AM	A-4	93	6.0	....	5	475
" 21	9.58AM	A-1	96	5.3	....	3	140
" 21	10.21AM	A-2	96	5.3	....	0	150
" 21	10.32AM	A-3	96	5.3	....	1	130
" 21	11.00AM	R	72	6.7	39	1	210
" 21	11.05AM	A-4	72	6.7	....	2	220
" 21	3.53PM	W-1	96	2.0	....	1	550
" 21	3.59PM	W-2	96	2.0	....	1	500
" 21	4.11PM	W-3	96	2.0	....	1	350
" 21	4.32PM	W-4	96	3.4	....	1	375
" 21	5.00PM	R	92	3.0	38	1	450
" 22	1.00AM	R	92	5.9	55	0	23
" 22	3.20AM	A-1	87	4.1	....	0	90
" 22	3.27AM	A-2	87	4.1	....	0	27
" 22	3.38AM	A-3	87	4.6	....	0	37
" 22	4.00AM	A-4	87	5.1	....	0	20
" 22	7.00AM	R	99	6.2	45	0	100
" 22	9.09AM	A-1	118	4.5	....	1	160
" 22	9.16AM	A-2	118	4.5	....	1	80
" 22	9.27AM	A-3	118	4.5	....	1	110
" 22	9.59AM	A-4	118	4.5	....	1	70
" 22	11.36AM	A-1	99	5.4	....	1	400
" 22	11.44AM	A-2	99	5.4	....	1	130
" 22	12.06PM	A-3	99	5.4	....	1	120
" 22	12.27PM	A-4	99	5.4	....	1	46
" 22	3.02PM	W-1	95	2.7	....	0	250
" 22	3.09PM	W-2	95	2.7	....	1	200
" 22	3.19PM	W-3	95	2.7	....	0	190
" 22	3.40PM	W-4	95	2.7	....	1	275
" 22	4.00PM	R	94	2.7	46	1	275
" 23	2.00AM	R	99	6.5	42	1	250
" 23	3.17AM	A-1	96	4.6	....	3	375

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 23	3.23AM	A-2	96	5.3	....	0	240
" 23	3.34AM	A-3	96	5.3	....	1	230
" 23	3.56AM	A-4	96	5.8	....	1	150
" 23	5.18AM	A-1	99	4.9	....	1	450
" 23	5.25AM	A-2	99	6.3	....	1	250
" 23	5.35AM	A-3	99	6.3	....	1	140
" 23	5.57AM	A-4	99	6.5	....	0	220
" 23	8.06AM	W-1	86	1.5	....	8	450
" 23	8.14AM	W-2	86	1.8	....	7	300
" 23	8.25AM	W-3	86	2.2	....	6	375
" 23	8.46AM	W-4	86	2.8	....	5	350
" 23	9.00AM	R	86	2 8	39	5	350
" 23	6.00PM	R	91	6.4	34	5	210
" 23	6.45PM	A-1	82	3.5	....	18	500
" 23	6.52PM	A-2	82	3.5	....	7	425
" 23	7.05PM	A-3	82	3.5	....	5	375
" 23	7.26PM	A-4	82	5.2	....	5	425
" 23	9.13PM	W-1	86	3.0	....	12	375
" 23	9.21PM	W-2	86	3.0	....	13	350
" 23	9.26PM	W-3	86	3.0	....	12	375
" 23	9.54PM	W-4	86	4.3	....	10	500
" 24	2.00AM	R	76	4.2	39	13	600
" 24	6.22AM	A-1	92	5.2	....	25	1,700
" 24	6.29AM	A-2	92	5.2	....	8	550
" 24	6.41AM	A-3	92	5.5	....	12	425
" 24	7.00AM	R	92	6.0	39	12	650
" 24	7.06AM	A-4	92	6.0	....	12	550
" 24	10.59AM	W-1	98	1.2	....	20	325
" 24	11.05AM	W-2	98	1.2	....	8	375
" 24	11.16AM	W-3	98	....	....	7	450
" 24	11.40AM	W-4	98	2.8	....	6	650
" 24	1.00PM	R	91	4.3	42	5	500
" 24	4.00PM	R	90	5.6	42	5	500
" 24	7.00PM	R	89	6.2	36	0	240
" 24	7.32PM	A-1	89	5.7	....	5	325
" 24	7.40PM	A-2	89	5.7	....	3	210
" 24	7.53PM	A-3	89	5.7	....	5	300
" 24	8.12PM	A-4	89	5.7	....	1	200
" 24	10.00PM	R	95	6.3	39	1	275
" 24	10.35PM	A-1	91	3.7	....	5	750
" 24	10.43PM	A-2	91	....	....	3	210
" 24	10.56PM	A-3	91	5.8	....	3	250
" 24	11.22PM	A-4	91	6.1	....	3	250
" 25	1.26AM	W-1	92	3.2	....	7	600
" 25	1.34AM	W-2	92	3.3	....	9	450
" 25	1.44AM	W-3	92	3.3	....	7	375

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 25	2.06AM	W-4	92	3.6	....	5	350
" 25	3.00AM	R	98	3.9	42	3	425
" 25	6.00AM	R	98	5.0	39	3	375
" 25	9.00AM	R	94	6.2	43	1	350
" 25	12.00AM	R	83	5.6	39	0	210
" 25	2.18PM	A-1	88	1.4	....	35	1,400
" 25	2.23PM	A-2	88	3.1	....	16	600
" 25	2.34PM	A-3	88	3.1	....	16	475
" 25	2.58PM	A-4	88	4.7	....	3	225
" 25	3.00PM	R	88	4.7	42	1	275
" 25	8.05PM	W-1	98	3.2	....	6	140
" 25	8.11PM	W-2	98	3.2	....	5	140
" 25	8.22PM	W-3	98	3.7	....	3	120
" 25	8.44PM	W-4	98	3.7	....	1	90
" 26	3.00AM	R	98	5.8	39	3	140
" 26	4.41AM	A-1	96	4.9	....	6	350
" 26	4.48AM	A-2	96	4.9	....	1	140
" 26	5 00AM	A-3	96	5.3	....	1	120
" 26	5.22AM	A-4	96	5.3	....	1	70
" 26	9.37AM	A-1	81	5.1	....	7	1,300
" 26	9.45AM	A-2	81	5.1	....	1	170
" 26	9.58AM	A-3	81	5.7	....	0	100
" 26	10.21AM	A-4	81	5.7	....	1	110
" 26	11.02AM	A-1	82	4.2	....	0	850
" 26	11.08AM	A-2	82	4.2	....	0	165
" 26	11.19AM	A-3	82	5.6	....	0	210
" 26	11.42AM	A-4	82	5.6	....	1	140
" 26	12.00M	R	90	6.0	39	1	170
" 26	12.59PM	W-1	103	2.6	....	7	275
" 26	1.08PM	W-2	103	2.7	....	3	650
" 26	1.19PM	W-3	103	....	....	5	275
" 26	1.42PM	W-4	103	3.0	....	1	325
" 26	3.00PM	R	95	4.0	41	0	275
" 26	9.56PM	A-1	99	4.7	....	0	325
" 26	10.03PM	A-2	99	4.7	....	1	140
" 26	10.14PM	A-3	99	....	....	0	100
" 26	10.35PM	A-4	99	4.9	....	0	130
" 27	1.00AM	R	96	6.0	42	0	130
" 27	2.16AM	A-1	95	5.2	....	5	500
" 27	2.23AM	A-2	95	5.3	....	0	160
" 27	2.34AM	A-3	95	5.3	....	1	160
" 27	2.57AM	A-4	95	5.8	....	1	180
" 27	4.30AM	A-1	103	5.1	....	5	550
" 27	4.37AM	A-2	103	5.3	....	1	230
" 27	4.48AM	A-3	103	5.6	....	1	400
" 27	5.10AM	A-4	103	6.0	....	1	250

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 27	6.53AM	W-1	103	3.0	....	8	425
" 27	7.00AM	W-2	103	3.2	....	7	800
" 27	7.12AM	W-3	103	....	....	6	700
" 27	7.33AM	W-4	103	3.7	....	6	750
" 27	8.00AM	R	96	3.1	34	6	650
" 27	2.28PM	A-1	94	3.8	....	10	1,300
" 27	2.34PM	A-2	94	3.8	....	5	700
" 27	2.46PM	A-3	94	....	....	3	550
" 27	3.10PM	A-4	94	4.7	....	1	325
" 27	4.00PM	R	78	5.7	35	1	475
" 27	6.10PM	A-1	104	3.2	....	7	800
" 27	6.16PM	A-2	104	....	....	3	275
" 27	6.34PM	A-3	104	5.1	....	3	200
" 27	6.55PM	A-4	104	6.0	....	3	225
" 27	7.54PM	W-1	103	3.7	....	7	375
" 27	8.00PM	W-2	103	3.7	....	7	300
" 27	8.11PM	W-3	103	....	....	5	300
" 27	8.33PM	W-4	103	3.9	....	5	375
" 28	2.00AM	R	98	6.1	38	1	325
" 28	3.23AM	A-1	89	5.3	....	5	900
" 28	3.30AM	A-2	89	....	....	1	325
" 28	3.41AM	A-3	89	....	....	3	325
" 28	4.04AM	A-4	89	5.7	....	3	375
" 28	5.16AM	A-1	101	6.0	....	9	1,100
" 28	5.22AM	A-2	101	....	....	5	450
" 28	5.33AM	A-3	101	6.3	....	3	450
" 28	5.56AM	A-4	101	6.5	....	3	400
" 28	6.50AM	W-1	101	3.2	....	16	1,000
" 28	6.57AM	W-2	101	3.2	....	13	1,300
" 28	7.08AM	W-3	101	....	....	10	800
" 28	7.29AM	W-4	101	4.1	....	10	700
" 28	9.00AM	R	86	3.6	34	9	850
" 28	3.00PM	R	89	5.8	32	3	400
" 28	4.25PM	A-1	77	2.7	....	13	1,700
" 28	4.32PM	A-2	77	....	....	7	550
" 28	4.44PM	A-3	77	5.0	....	7	425
" 28	5.08PM	A-4	77	5.0	....	5	375
" 28	7.33PM	A-1	79	6.1	....	5	350
" 28	7.41PM	A-2	79	6.2	....	5	225
" 28	7.52PM	A-3	79	6.2	....	3	450
" 28	8.17PM	A-4	79	6.2	....	1	250
" 28	10.12PM	A-1	100	6.7	....	10	750
" 28	10.18PM	A-2	100	6.7	....	5	400
" 28	10.29PM	A-3	100	6.8	....	5	300
" 28	10.51PM	A-4	100	7.0	....	5	350
" 28	11.00PM	R	102	7.0	34	5	200

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 29	12.25AM	W-1	96	3.2	....	25	950
" 29	12.31AM	W-2	96	3.2	....	16	700
" 29	12.42AM	W-3	96	3.8	....	16	425
" 29	1.05AM	W-4	96	3.8	....	16	425
" 29	7.00AM	R	96	6.1	35	10	550
" 29	10.58AM	A-1	80	2.4	....	75	500
" 29	11.05AM	A-2	80	2.4	....	7	750
" 29	11.15AM	A-3	80	....	....	5	600
" 29	11.39AM	A-4	80	6.3	....	5	750
" 29	1.00PM	R	87	7.1	35	3	475
" 29	3.06PM	A-1	92	4.9	....	7	1,400
" 29	3.13PM	A-2	92	....	....	3	650
" 29	3.24PM	A-3	92	6.8	....	3	425
" 29	3.49PM	A-4	92	....	....	3	450
" 29	4.00PM	R	94	7.5	36	3	500
" 29	5.20PM	W-1	100	....	....	13	550
" 29	5.27PM	W-2	100	3.5	....	13	475
" 29	5.37PM	W-3	100	....	....	12	500
" 29	6.00PM	W & R	100	3.9	....	12	475
" 29	8.00PM	R	96	4.6	39	5	475
" 29	11.00PM	R	100	6.0	42	3	300
" 30	2.00AM	R	89	6.5	36	3	450
" 30	2.11AM	A-1	97	5.8	....	25	950
" 30	2.18AM	A-2	97	5.8	....	7	600
" 30	2.29AM	A-3	97	5.8	....	5	425
" 30	2.52AM	A-4	97	6.0	....	3	700
" 30	3.49AM	A-1	96	6.0	....	25	1,100
" 30	3.56AM	A-2	96	6.1	....	7	350
" 30	4.08AM	A-3	96	6.2	....	5	475
" 30	4.29AM	A-4	96	6.4	....	3	350
" 30	5.00AM	R	97	6.8	38	3	425
" 30	6.05AM	W-1	96	3.3	....	20	700
" 30	6.12AM	W-2	96	3.3	....	16	550
" 30	6.23AM	W-3	96	3.7	....	13	425
" 30	6.45AM	W-4	96	3.7	....	7	450
" 30	7.00AM	R	110	3.9	42	7	550
" 30	10.00AM	R	95	5.2	45	5	275
" 30	2.35PM	A-1	87	3.6	....	7	500
" 30	2.41PM	A-2	87	....	....	5	450
" 30	2.49PM	A-3	87	....	....	5	325
" 30	3.12PM	A-4	87	4.6	....	5	475
" 30	8.54PM	A-1	88	6.2	....	20	750
" 30	9.00PM	R	88	6.2	42	5	400
" 30	9.02PM	A-2	88	6.2	....	10	450
" 30	9.13PM	A-3	88	6.3	....	10	350
" 30	9.35PM	A-4	88	6.3	....	7	350

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 30	11.00PM	R	105	7.1	42	5	275
" 30	11.29PM	A-1	92	6.2	....	40	2,400
" 30	11.36PM	A-2	92	6.2	....	13	350
" 30	11.46PM	A-3	92	6.2	....	10	300
" 31	12.09AM	A-4	92	6.2	....	10	375
" 31	2.11AM	W-1	90	3.0	....	25	900
" 31	2.18AM	W-2	90	3.0	....	25	700
" 31	2.29AM	W-3	90	3.0	....	20	750
" 31	2.50AM	W-4	90	3.1	....	23	750
" 31	4.00AM	R	104	3.5	38	20	700
" 31	8.00AM	R	90	4.8	39	25	3,000
" 31	2.20PM	A-1	87	2.9	....	40	1,500
" 31	2.27PM	A-2	87	....	....	35	550
" 31	2.42PM	A-3	87	4.8	....	16	650
" 31	3.11PM	A-4	87	5.5	....	13	500
" 31	4.00PM	R	91	6.2	43	5	750
" 31	7.21PM	A-1	82	6.1	....	35	1,100
" 31	7.30PM	A-2	82	6.0	....	10	220
" 31	7.46PM	A-3	82	....	....	10	200
" 31	8.14PM	A-4	82	6.9	....	7	300
" 31	9.31PM	W-1	71	1.9	....	32	1,000
" 31	9.40PM	W-2	71	....	....	25	700
" 31	9.56PM	W-3	71	2.4	....	20	650
" 31	10.30PM	W-4	71	3.0	....	20	600
" 31	11.00PM	R	93	3.3	48	18	325
April 1	6.00AM	R	77	3.5	17	89	4,500
" 2	6.00AM	W-1	81	3.0	....	1	220
" 2	6.10AM	W-2	81	....	....	1	275
" 2	6.23AM	W-3	81	....	....	1	170
" 2	6.45AM	W-4	81	3.2	....	0	140
" 2	7.00AM	R	111	3.8	84	1	220
" 2	9.00AM	R	97	3.7	92	0	240
" 2	4.00PM	R	102	4.6	81	3	80
" 2	7.00PM	R	100	5.2	74	0	75
" 2	10.00PM	R	100	6.3	71	3	110
" 3	1.00AM	R	99	6.4	50	0	180
" 3	2.31AM	A-1	95	5.5	....	3	375
" 3	2.37AM	A-2	95	....	....	0	130
" 3	2.50AM	A-3	95	5.9	....	1	120
" 3	3.12AM	A-4	95	6.0	....	1	190
" 3	4.00AM	R	99	6.3	57	0	200
" 3	5.39AM	A-1	99	6.1	....	75	3,200
" 3	5.46AM	A-2	99	....	....	13	475
" 3	5.57AM	A-3	99	6.1	....	13	350
" 3	6.19AM	A-4	99	6.2	....	13	425
" 3	7.00AM	R	97	6.3	22	13	300

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 3	10.00AM	R	95	6.9	14	7	275
" 3	11.30AM	W-1	80	1.4	....	35	1,400
" 3	11.37AM	W-2	80	....	....	13	350
" 3	11.48AM	W-3	80	1.4	....	5	130
" 3	12.11PM	W-4	80	2.5	....	10	170
" 3	3.00PM	R	88	3.6	36	0	160
" 3	4.53PM	A-1	77	3.0	....	5	300
" 3	5.00PM	A-2	77	3.0	....	5	120
" 3	5.11PM	A-3	77	....	....	1	95
" 3	5.35PM	A-4	77	3.4	....	0	100
" 4	2.00AM	R	85	7.0	14	1	130
" 4	2.35AM	A-1	78	3.6	....	7	425
" 4	2.43AM	A-2	78	3.8	....	3	300
" 4	2.50AM	A-3	78	....	....	0	220
" 4	3.17AM	A-4	78	5.0	....	1	325
" 4	8.00AM	R	103	6.6	6	1	170
" 4	10.41AM	A-1	93	4.2	....	20	750
" 4	10.48AM	A-2	93	....		5	375
" 4	11.00AM	A-3	93	4.7	....	1	300
" 4	11.22AM	A-4	93	4.8	....	1	110
" 4	3.00PM	R	87	6.6	10	0	150
" 4	4.10PM	A-1	92	1.5	....	60	1,100
" 4	4.19PM	A-2	92	....	....	5	250
" 4	4.26PM	A-3	92	4.8	....	3	300
" 4	4.50PM	A-4	92	5.3	....	1	230
" 4	6.39PM	W-1	99	3.0	....	15	350
" 4	6.46PM	W-2	99	3.0	....	13	700
" 4	6.57PM	W-3	99	3.0	....	5	180
" 4	7.20PM	W-4	99	3.0	....	0	130
" 4	11.00PM	R	99	3.9	69	0	31
" 5	3.00AM	R	102	5.7	70	0	44
" 5	5.47AM	A-1	94	3.1	....	0	275
" 5	5.54AM	A-2	94	....	....	0	41
" 5	6.05AM	A-3	94	4.4	....	0	60
" 5	6.26AM	A-4	94	4.5	....	0	65
" 5	9.00AM	R	96	5.2	18	3	180
" 5	2.00PM	R	84	6.4	7	1	170
" 5	2.37PM	A-1	103	3.2	....	45	350
" 5	2.44PM	A-2	103	....	....	7	400
" 5	2.57PM	A-3	103	4.9	....	3	300
" 5	3.22PM	A-4	103	4.9	....	1	180
" 5	9.00PM	R	99	6.4	....	1	19
" 5	9.47PM	A-1	79	4.9	....	7	650
" 5	9.54PM	A-2	79	....	....	1	300
" 5	10.05PM	A-3	79	5.2	....	1	150
" 5	10.26PM	A-4	79	5.6	....	1	180

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 6.....	3.00AM	R	100	6.7	0 / 189 †	1	300
" 6.....	5.14AM	A-1	94	5.0	...	50	4,500
" 6.....	5.24AM	A-2	94	5.9	...	7	300
" 6.....	5.35AM	A-3	94	5.9	...	5	300
" 6.....	5.57AM	A-4	94	6.4	...	1	160
" 6.....	8.00AM	R	100	6.6	0 / 173 †	1	120
" 6.....	11.29AM	W-1	106	5.5	...	15	375
" 6.....	11.35AM	W-2	106	5.5	...	12	325
" 6.....	11.47AM	W-3	106	5.5	...	10	300
" 6.....	12.15PM	W-4	106	5.6	...	5	190
" 6	1.00PM	R	100	3.1	0 / 160 †	1	190
" 6.....	8.00PM	R	102	4.8	0 / 142 †	1	170
" 7	2.00AM	R	100	5.8	6	0	160
" 7.....	7.00AM	R	97	7.1	8	0	140
" 7.....	9.26AM	A-1	82	2.8	...	18	600
" 7.....	9.35AM	A-2	82	3.6	...	5	325
" 7.....	9.48AM	A-3	82	...	...	3	200
" 7.....	10.10AM	A-4	82	4.3	...	3	180
" 7.....	2.00PM	R	100	5.4	0 / 120 †	0	170
" 7.....	10.00PM	R	101	6.3	2	0	220
" 8.....	3.00AM	R	96	6.9	0 / 120 †	0	170
" 8.....	5.30AM	A-1	94	5.3	...	13	2,000
" 8	5.39AM	A-2	94	5.3	...	0	275
" 8.....	5.50AM	A-3	94	...	...	0	275
" 8.....	6.14AM	A-4	94	6.2	...	0	210
" 8.....	8.00AM	R	100	6.2	6	0	140
" 8.....	3.00PM	R	98	7.0	0 / 101 †	0	240
" 8.....	4.46PM	A-1	70	2.4	...	20	3,400
" 8.....	4.55PM	A-2	70	...	...	1	475
" 8.....	5.09PM	A-3	70	4.7	...	1	475
" 8.....	5.37PM	A-4	70	6.3	...	0	350

† Total alkalinity.

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples. Date—1899.	Hour.	Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million. Excess of Lime.	Parts per Million. Suspended Matter.	Bacteria per Cubic Centimeter.
April 8.....	11.00PM	R	98	7.2	0 44 †	1	450
" 9.....	12.35AM	W-1	98	2.3	...	20	1,700
" 9.....	12.41AM	W-2	98	2.3	...	15	900
" 9.....	12.52AM	W-3	98	2.3	...	10	500
" 9.....	1.15AM	W-4	98	2.3	...	7	275
" 9.....	6.00AM	R	95	3.2	0 94 †	1	275
" 9.....	12.00M	R	100	3.6	0 115 †	1	325
" 9.....	7.00PM	R	99	4.3	0 86 †	3	450
" 10.....	1.00AM	R	100	4.7	0 110 †	1	325
" 10.....	5.00AM	R	102	4.9	0 88 †	5	375
" 10.....	9.00AM	R	97	5.4	0 105 †	5	300
" 10.....	3.00PM	R	101	4.9	0 117 †	1	350
" 10.....	8.00PM	R	99	5.6	5	1	500
" 11.....	1.00AM	R	99	4.7	6	1	650
" 11.....	1.48AM	A-1	99	4.7	...	25	4,900
" 11.....	1.55AM	A-2	99	4.7	...	7	900
" 11.....	2.06AM	A-3	99	4.8	...	7	800
" 11.....	2.28AM	A-4	99	5.3	...	5	475
" 11.....	7.00AM	R	100	6.0	0 86 †	7	550
" 11.....	11.32AM	W-1	86	2.0	...	64	10,000
" 11.....	11.38AM	W-2	86	2.0	...	18	4,600
" 11.....	11.51AM	W-3	86	...	...	13	1,700
" 11.....	12.22PM	W-4	86	2.4	...	10	750
" 11.....	4.00PM	R	94	3.0	0 74 †	5	550
" 11.....	11.00PM	R	99	3.8	0 109 †	1	700
" 12.....	4.00AM	R	101	4.3	0 102 †	3	650
" 12.....	9.00AM	R	86	3 7	0 98 †	1	650
" 12.....	6.55PM	W-1	96	2.8	...	3	700
" 12.....	7.00PM	W-2	96	2.8	...	2	600
" 12.....	7.06PM	W-3	96	...	...	2	325
" 12.....	7.31PM	W-4	96	3.0	...	2	210

† Total alkalinity.

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 12	8.00PM	R	98	3.4	34	1	250
" 13	1.00AM	R	100	4.1	39	1	110
" 13	5.00AM	R	100	5.4	36	1	130
" 13	9.15AM	A-1	108	3.9	....	0	425
" 13	9.23AM	A-2	108	....	....	0	180
" 13	9.33AM	A-3	108	....	....	0	170
" 13	9.55AM	A-4	108	4.1	....	0	130
" 13	11.00AM	R	105	4.5	66	0	120
" 13	2.14PM	A-1	97	4.3	....	0	75
" 13	2.21PM	A-2	97	....	....	0	75
" 13	2.31PM	A-3	97	....	....	0	70
" 13	2.55PM	A-4	97	4.4	....	0	50
" 13	3.00PM	R	97	4.4	48	1	38
" 13	9.00PM	R	67	6.6	50	0	8
" 13	10.12PM	W-1	103	2.6	....	1	200
" 13	10.18PM	W-2	103	....	....	0	90
" 13	10.29PM	W-3	103	....	....	0	55
" 13	10.52PM	W-4	103	2.9	....	0	30
" 14	2.00AM	R	103	4.1	53	0	4
" 14	5.36AM	A-1	100	2.8	....	0	55
" 14	5.42AM	A-2	100	....	....	0	12
" 14	5.53AM	A-3	100	2.9	....	0	14
" 14	6.14AM	A-4	100	2.9	....	0	14
" 14	8.00AM	R	102	4.0	50	0	18
" 14	2.18PM	A-1	103	3.2	....	0	60
" 14	2.24PM	A-2	103	3.8	....	0	24
" 14	2.34PM	A-3	103	3.8	....	0	55
" 14	2.55PM	A-4	103	4.0	....	0	47
" 14	9.13PM	W-1	55	1.2	....	0	6
" 14	9.28PM	W-2	55	1.2	....	0	30
" 14	9.39PM	W-3	55	1.2	....	0	9
" 14	10.00PM	R	55	1.2	45	0	41
" 14	10.14PM	W-4	55	1.3	....	0	10
" 14	11.00PM	R	63	1.4	45	0	5
" 15	5.00AM	R	103	3.5	49	0	12
" 15	10.00AM	R	91	5.6	50	0	15
" 15	11.10AM	A-1	83	2.2	....	0	28
" 15	11.16AM	A-2	83	....	....	0	17
" 15	11.25AM	A-3	83	....	....	0	9
" 15	11.47AM	A-4	83	2.5	....	0	13
" 15	5.00PM	R	103	5.9	50	0	5
" 15	7.11PM	A-1	91	3.4	....	0	0
" 15	7.18PM	A-2	91	....	....	0	2
" 15	7.30PM	A-3	91	3.8	....	0	2
" 15	7.54PM	A-4	91	4.2	....	0	3
" 15	10.10PM	A-1	102	4.2	....	0	1

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 15	10.17PM	A-2	102	....	....	0	5
" 15	10.27PM	A-3	102	4.7	....	0	9
" 15	10.49PM	A-4	102	5.0	....	0	5
" 15	11.57PM	A-1	100	4.2	....	0	3
" 16	12.04AM	A-2	100	4.2	.. .	0	2
" 16	12.14AM	A-3	100	....	....	0	1
" 16	12.35AM	A-4	100	4.8	....	0	2
" 16	1.00AM	R	106	4.8	53	0	4
" 16	2.03AM	A-1	100	5.8	....	0	3
" 16	2.09AM	A-2	100	....	....	0	3
" 16	2.20AM	A-3	100	5.5	....	0	0
" 16	2.41AM	A-4	100	5.5	....	0	2
" 16	4.35AM	W-1	102	1.8	....	0	600
" 16	4.40AM	W-2	102	1.9	....	0	80
" 16	4.51AM	W-3	102	....	....	0	18
" 16	5.12AM	W-4	102	2.0	....	0	11
" 16	6.00AM	R	110	3.5	48	0	0
" 16	11.00AM	R	100	5.2	42	0	6
" 16	12.10PM	A-1	95	2.9	....	0	33
" 16	12.17PM	A-2	95	....	....	0	9
" 16	12.27PM	A-3	95	3.1	....	0	12
" 16	12.48PM	A-4	95	3.4	....	0	11
" 16	5.00PM	R	104	5.8	42	0	7
" 16	6.34PM	A-1	104	3.3	....	0	6
" 16	6.40PM	A-2	104	3.8	....	0	5
" 16	6.50PM	A-3	104	4.4	....	0	4
" 16	7.12PM	A-4	104	....	....	0	11
" 16	9.50PM	A-1	90	3.5	....	0	10
" 16	9.56PM	A-2	90	3.8	....	0	2
" 16	10 07PM	A-3	90	....	....	0	9
" 16	10.30PM	A-4	90	4.4	....	0	4
" 16	12.00PM	R	102	5.7	45	0	14
" 17	12.49AM	A-1	94	3.8	....	0	7
" 17	12.55AM	A-2	94	4.1	....	0	9
" 17	1.06AM	A-3	94	4.2	....	0	2
" 17	1.27AM	A-4	94	5.0	....	0	6
" 17	2.40AM	A-1	97	3.8	....	0	6
" 17	2.47AM	A-2	97	....	....	0	4
" 17	2.59AM	A-3	97	4.4	...	0	3
" 17	3.20AM	A-4	97	5.2	....	0	2
" 17	4.30AM	R	100	6.1	50	0	4
" 18	4.30AM	R	80	1.4	....	0	16
" 18	6.30AM	R	54	1.5	....	0	38
" 18	8.30AM	R	88	1.2	....	0	48
" 18	4.00PM	R	93	4.3	42	0	23
" 18	10.00PM	R	75	6.7	36	0	0

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 18	10.15PM	A-1	66	3.2	....	0	7
" 18	10.24PM	A-2	66	3.6	....	0	5
" 18	10.37PM	A-3	66	3.6	....	0	3
" 18	11.05PM	A-4	66	3.3	....	0	3
" 19	3.00AM	R	85	6.3	39	0	17
" 19	5.09AM	A-1	82	....	....	1	14
" 19	5.18AM	A-2	82	4.9	....	0	6
" 19	5.30AM	A-3	82	4.9	....	0	7
" 19	5.46AM	A-4	82	4.9	....	0	3
" 19	9.00AM	R	88	6.6	45	0	6
" 19	11.36AM	A-1	98	4.3	....	0	16
" 19	11.43AM	A-2	98	....	....	0	7
" 19	11.54AM	A-3	98	5.2	....	0	7
" 19	12.15PM	A-4	98	5.3	....	0	16
" 19	2.30PM	R	93	6.3	42	0	5
" 19	3.34PM	W-1	98	2.1	....	0	24,750
" 19	3.41PM	W-2	98	2.1	....	0	5,300
" 19	3.53PM	W-3	98	2.2	....	0	3,600
" 19	4.14PM	W-4	98	2.2	....	0	1,200
" 19	9.00PM	R	100	3.7	34	0	33
" 20	2.00AM	R	97	6.0	31	0	46
" 20	2.15AM	A-1	100	3.8	....	0	700
" 20	2.21AM	A-2	100	3.8	....	0	110
" 20	2.32AM	A-3	100	3.8	....	0	50
" 20	2.54AM	A-4	100	4.1	....	0	65
" 20	8.00AM	R	93	5.9	25	0	65
" 20	10.05AM	A-1	95	4.1	....	0	130
" 20	10.12AM	A-2	95	4.1	....	0	26
" 20	10.23AM	A-3	95	4.2	....	0	23
" 20	10.46AM	A-4	95	4.3	....	0	16
" 20	3.00PM	W-1	109	2.2	....	0	18,900
" 20	3.06PM	W-2	109	2.2	....	0	8,300
" 20	3.17PM	W-3	109	....	....	0	4 600
" 20	3.38PM	W-4	109	2.5	....	0	1,700
" 20	4.00PM	R	81	2.0	25	0	2,300
" 20	10.00PM	R	104	3.9	25	0	90
" 21	3.00AM	R	97	6.2	25	0	55
" 21	3.26AM	A-1	100	3.0	....	0	350
" 21	3.33AM	A-2	100	3.1	....	0	95
" 21	3.44AM	A-3	100	....	....	0	80
" 21	4.05AM	A-4	100	3.6	....	0	42
" 21	8.00AM	R	98	5.9	28	0	55
" 21	8.30AM	A-1	94	3.2	....	0	375
" 21	8.38AM	A-2	94	3.2	....	0	90
" 21	8.45AM	A-3	94	....	....	0	70
" 21	9.12AM	A-4	94	3.5	....	0	50

TABLE No. 7—*Results of the Examination of the Effluent of the Sand Filter*—(Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 21	1.00PM	R	90	6.4	31	0	23
" 21	2.00PM	A-1	102	3.4	....	0	85
" 21	2.07PM	A-2	102	3.6	....	0	46
" 21	2.19PM	A-3	102	....	....	0	19
" 21	2.41PM	A-4	102	4.0	....	0	20
" 21	4.15PM	W-1	97	2.1	....	0	15,700
" 21	4.21PM	W-2	97	....	....	0	9,100
" 21	4.32PM	W-3	97	2.4	....	0	2,100
" 21	4.53PM	W-4	97	2.8	....	0	1,100
" 21	8.00PM	R	103	2.6	....	0	140
" 22	1.00AM	R	98	4.7	25	0	180
" 22	4.16AM	A-1	107	3.0	....	0	160
" 22	4.24AM	A-2	107	3.3	....	0	95
" 22	4.35AM	A-3	107	....	....	0	80
" 22	4.57AM	A-4	107	3.6	....	0	50
" 22	8.00AM	R	99	5.5	25	0	36
" 22	9.08AM	A-1	101	2.7	....	0	240
" 22	9.15AM	A-2	101	....	....	0	80
" 22	9.26AM	A-3	101	3.6	....	0	55
" 22	9.47AM	A-4	101	3.7	....	0	36
" 22	1.28PM	A-1	90	3.2	....	0	120
" 22	1.34PM	A-2	90	3.3	....	0	33
" 22	1.45PM	A-3	90	....	....	0	50
" 22	2.00PM	R	90	3.3	31	0	42
" 22	2.08PM	A-4	90	3.3	....	0	49
" 22	6.55PM	A-1	101	4.1	....	0	70
" 22	7 01PM	A-2	101	4.6	....	0	10
" 22	7.12PM	A-3	101	....	....	0	16
" 22	7.33PM	A-4	101	5.3	....	0	17
" 22	9.00PM	R	95	6.2	28	0	6
" 22	9.17PM	A-1	107	4.1	....	0	26
" 22	9.23PM	A-2	107	....	....	0	16
" 22	9.34PM	A-3	107	4.5	....	0	10
" 22	9.56PM	A-4	107	5.0	....	0	17
" 22	11.48PM	A-1	101	4.0		0	20
" 22	11.54PM	A-2	101	4.0	....	0	16
" 23	12.08AM	A-3	101	....	....	0	14
" 23	12.27AM	A-4	101	4.5	....	0	23
" 23	1.58AM	W-1	107	1.7	....	0	6,700
" 23	2.06AM	W-2	107	....	....	0	7,900
" 23	2.16AM	W-3	107	....	....	0	850
" 23	2.37AM	W-4	107	1.9	....	0	650
" 23	3.00AM	R	104	2.0	34	0	350
" 23	11.00AM	R	101	4.6	27	0	44
" 23	1.19PM	A-1	99	2.7	....	0	160
" 23	1.26PM	A-2	99	....	....	0	65

TABLE No. 7 — *Results of the Examination of the Effluent of the Sand Filter* — (Concluded).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 23	1.36PM	A-3	99	2.6	....	0	50
" 23	1.58PM	A-4	99	2.8	....	0	29
" 23	4.00PM	R	98	3.6	25	0	43
" 23	9.08PM	A-1	106	4.0	....	0	33
" 23	9.15PM	A-2	106	....	....	0	11
" 23	9.26PM	A-3	106	4.0	....	0	16
" 23	9.48PM	A-4	106	4.1	....	0	18
" 23	11.00PM	R	99	4.5	25	0	23
" 24	1.23AM	A-1	108	3.5	....	0	65
" 24	1.30AM	A-2	108	3.8	....	0	31
" 24	1.41AM	A-3	108	....	....	0	21
" 24	2.03AM	A-4	108	4.4	....	0	11
" 24	3.00AM	R	100	5.1	28	0	14
" 24	5.08AM	A-1	106	3.9	....	0	47
" 24	5.15AM	A-2	106	....	....	0	34
" 24	5.26AM	A-3	106	4.1	....	0	24
" 24	5.47AM	A-4	106	4.1	....	0	10
" 24	8.00AM	R	100	5.1	25	0	29
" 24	10.10AM	W-1	97	1.8	....	0	7,000
" 24	10.16AM	W-2	97	1.8	....	0	1,600
" 24	10.27AM	W-3	97	....	....	0	900
" 24	10.49AM	W-4	97	1.9	..	0	500
" 24	1.00PM	R	102	1.8	24	0	180
" 24	9.00PM	R	101	4.2	20	0	80
" 25	1.43AM	A-1	107	3.2	....	0	210
" 25	1.50AM	A-2	107	3.2	....	0	110
" 25	2.01AM	A-3	107	....	....	0	50
" 25	2.22AM	A-4	107	2.9	....	0	55
" 25	3.00AM	R	98	3.3	22	0	36
" 25	9.00AM	R	95	5.4	21	0	29
" 25	10.22AM	A-1	101	3.2	....	0	240
" 25	10.29AM	A-2	101	....	....	0	60
" 25	10.40AM	A-3	101	3.2	....	0	75
" 25	11.02AM	A-4	101	3.8	....	0	60
" 25	1.00PM	R	99	4.3	18	0	49
" 25	5.00PM	R	87	6.1	20	0	32

TABLE NO. 8—*Results of the Examination of the Effluent of the Polarite Filter.*

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 13.....	11.00PM	R	79	2.4	80	0	25
" 14.....	4.00AM	"	76	2.4	85	0	11
" 14.....	12.00M	"	66	2.0	67	0	18
" 14.....	10.20PM	"	77	2.4	69	0	23
" 15.....	5.00AM	"	78	2.4	70	0	18
" 15.....	7.10PM	"	63	2.6	78	0	5
" 15.....	11.00PM	"	80	2.1	81	0	7
" 16.....	6.00AM	"	71	2.0	81	0	1
" 16.....	6.00PM	"	89	2.1	70	0	4
" 17.....	1.00AM	"	96	2.1	64	0	6
" 17.....	8.30AM	"	95	2.0	63	0	11
" 17.....	3.00PM	"	69	1.7	64	0	4
" 18.....	7.00AM	"	97	1.7	56	0	6
" 18.....	3.00PM	"	102	1.8	56	0	0
" 19.....	3.00AM	"	96	1 5	48	0	0
" 19.....	11.00AM	"	97	1.5	39	0	2
" 19.....	5.00PM	"	96	1.5	38	0	3
" 19...	12.00PM	"	104	1.5	36	0	7
" 20.....	7.00AM	"	99	1.6	38	0	100
" 20.....	2.00PM	"	72	1.2	34	0	230
" 20.....	8.00PM	"	100	1.6	39	0	250
" 20.....	11.00PM	"	97	1.7	36	0	350
" 21.....	1.00AM	"	102	1.8	34	0	210
" 21.....	4.00AM	"	98	1.9	39	0	325
" 21.....	7.00AM	"	82	1.5	34	0	400
" 21.....	11.00AM	"	63	1.8	34	0	130
" 21.....	5.00PM	"	95	1.8	36	0	350
" 22.....	1.00AM	"	92	1.9	50	0	11
" 22.....	7.00AM	"	99	1.9	48	0	33
" 22.....	4.00PM	"	100	1.8	42	0	190
" 23.....	2.00AM	"	102	1.9	42	0	95

TABLE No. 8 — *Results of the Examination of the Effluent of the Polarite Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 23.....	9.00AM	R	101	1.9	39	0	325
" 23.....	6.00PM	"	92	2.0	36	1	220
" 24.....	2.00AM	"	95	2.4	31	3	350
" 24	7.00AM	"	98	2.7	35	1	550
" 24.....	1.00PM	"	91	2.9	35	1	375
" 24.....	4.00PM	"	90	2.9	36	0	250
" 24.....	7.00PM	"	92	3.0	41	1	130
" 24.....	10.00PM	"	98	3 2	36	0	120
" 25.....	3.00AM	"	98	3.4	42	0	300
" 25.....	6.00AM	"	98	3 6	39	0	240
" 25.....	9.00AM	"	94	3.6	38	0	220
" 25.....	12.00M	"	81	3.7	39	0	220
" 25.....	3.00PM	"	91	3.5	39	0	325
" 26.....	3.00AM	"	98	4.4	36	0	110
" 26.....	12.00M	"	91	4.6	38	1	130
" 26.....	3.00PM	"	101	4.6	38	0	160
" 27.....	1.00AM	"	99	4.6	39	0	75
" 27.....	4.30AM	A-1	103	2.5	...	1	800
" 27.....	4.37AM	A-2	103	2.5	...	6	1,400
" 27.....	4.48AM	A-3	103	2.5	...	0	375
" 27.....	5.10AM	A-4	103	2.5	...	0	230
" 27.....	8.00AM	R	99	3.0	39	1	300
" 27.....	4.00PM	"	78	3.0	34	1	275
" 28.....	2.00AM	"	98	4.0	35	1	220
" 28.....	9.00AM	"	93	4.0	32	1	550
" 28...	3.00PM	"	89	4.4	34	0	350
" 28.....	11.00PM	"	98	...	31	1	210
" 29.....	7.00AM	"	99	4 2	34	1	650
" 29	1.30PM	"	90	4.3	31	0	375
" 29.....	5.20PM	A-1	96	4.1	34	3	450
" 29.....	5.27PM	A-2	96	4.1	...	5	1,000

TABLE No. 8 — *Results of the Examination of the Effluent of the Polarite Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
March 29.....	5.37PM	A-3	96	4.1	...	1	500
" 29..... ...	6.00PM	A-4	96	4.1	...	0	450
" 29.....	8.30PM	R	96	4.6	35	0	375
" 29.....	11.30PM	"	100	4.7	36	0	300
" 30.....	2.30AM	"	89	*	36	0	650
" 30.....	7.30AM	"	101	5.1	38	0	400
" 30.....	10.30AM	"	98	*	39	1	190
" 30.....	4.00PM	A-1	98	4.3	40	3	375
" 30.....	4.08PM	A-2	98	4.3	...	7	800
" 30.....	4.18PM	A-3	98	4.3	...	3	210
" 30.....	4.40PM	A-4	98	4.3	...	3	325
" 30.....	9.00PM	R	94	*	41	0	230
" 30.....	11.00PM	"	99	*	42	1	375
" 31.....	2.11AM	W-1	88	3.0	...	18	950
" 31.....	2.18AM	W-2	88	3.0	...	16	800
" 31.....	2.29AM	W-3	88	3.0	...	13	700
" 31.....	2.50AM	W-4	88	3.0	...	12	400
" 31.....	4.00AM	R	95	3.5	42	12	600
" 31.....	8.00AM	"	93	3.6	39	13	1,000
" 31.....	4.00PM	"	97	4.1	41	7	600
" 31.....	11.00PM	"	93	3.7	45	10	325
April 1.....	6.00AM	"	81	4.0	20	46	3,100
" 2.....	7.00AM	"	94	3.8	59	0	200
" 2.....	9.00AM	"	94	3.8	77	0	170
" 2.....	11.14AM	W-1	79	1.8	...	7	450
" 2.....	11.28AM	W-2	79	1.8	...	5	300
" 2.....	11.36AM	W-3	79	1.8	...	3	325
" 2.....	11.59AM	W-4	79	1.8	...	3	300
" 2.....	4.00PM	R	102	2.3	73	0	80
" 2.....	7.00PM	"	100	2.5	70	1	75
" 2...	10.00PM	"	101	2.5	70	0	85

* Not indicated by gage.

TABLE No. 8 — *Results of the Examination of the Effluent of the Polarite Filter* — (Continued).

Collection of Samples. Date—1899.	Hour.	Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million. Excess of Lime.	Parts per Million. Suspended Matter.	Bacteria per Cubic Centimeter.
April 3.....	1.00AM	R	99	2.4	35	3	210
" 3.....	4.00AM	"	96	2.6	48	0	190
" 3.....	7.00AM	"	97	2 7	22	7	300
" 3	10.00AM	"	98	2.9	18	5	275
" 3.....	3.00PM	"	90	2.7	34	0	95
" 4.....	2.00AM	"	98	3.0	...	1	180
" 4.....	8.00AM	"	103	3.0	8	1	180
" 4.....	3.00PM	"	94	2.7	11	0	140
" 4.....	11.00PM	"	99	2.8	48	0	41
" 5.....	3.00AM	"	101	2.8	57	0	42
" 5.....	9.00AM	"	99	2.7	32	1	130
" 5.....	2.00PM	"	94	2.4	11	1	150
" 5.....	9.00PM	"	100	2.4	...	1	38
" 6.....	3.00AM	"	100	2.3	0 190 †	0	150
" 6	8.00AM	"	100	2.2	0 174 †	0	140
" 6.....	1.00PM	"	100	2.2	0 141 †	0	275
" 6.....	8.00PM	"	102	2.2	11	0	140
" 7.....	2.00AM	"	100	2.2	8	0	150
" 7.....	7.00AM	"	98	2.2	6	0	110
" 7.....	2.00PM	"	101	2.2	0 124 †	0	130
" 7.....	10.00PM	"	101	2.2	0 103 †	0	180
" 8.....	3.00AM	"	96	2.2	0 116 †	0	140
" 8.....	8.00AM	"	100	2.2	0 88 †	0	150
" 8.....	3.00PM	"	98	2.2	0 105 †	0	250
" 8.....	11.00PM	"	97	2.2	0 92 †	0	275
" 9.....	6.00AM	"	95	2.4	0 87 †	0	240
" 9.....	12.00M	"	100	2.3	0 109 †	1	300
" 9.....	7.00PM	"	97	2.4	0 80 †	1	275
" 10.....	1.00AM	"	104	2.5	0 107 †	5	250
" 10.....	5.00AM	"	102	2.6	0 95 †	1	275
" 10.....	9.00AM	"	100	2.5	6	3	350

† Total alkalinity,

TABLE No. 8 — *Results of the Examination of the Effluent of the Polarite Filter* — (Continued).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 10.....	3.00PM	R	101	2.6	8	0	325
" 10.....	8.00PM	"	100	2.6	6	0	540
" 11.....	1.00AM	"	97	2.6	6	0	750
" 11.....	7.00AM	"	100	2.8	3	1	550
" 11.....	4.00PM	"	95	2.8	0 / 93 †	1	600
" 11.....	11.00PM	"	100	3.1	...	..	600
" 12.....	4.00AM	"	101	3.3	0 / 106 †	0	400
" 12.....	9.00AM	"	100	3.1	0 / 98 †	0	800
" 12.....	8.00PM	"	98	2.7	8	5	300
" 13.....	1.00AM	"	100	2.8	27	2	250
" 13.....	5.00AM	"	100	2.8	28	1	210
" 13.....	11.00AM	"	102	2.8	14	0	375
" 13.....	3.00PM	"	97	2.7	0 / 94 †	0	180
" 13.....	9.00PM	"	58	1.9	0 / 89 †	0	200
" 14.....	2.00AM	"	102	2.6	0 / 92 †	0	500
" 14.....	8.00AM	"	102	2.6	0 / 88 †	0	190
" 14.....	10.00PM	"	64	*	0 / 75 †	1	425
" 14.....	11.00PM	"	62	*	0 / 82 †	0	220
" 15.....	5.00AM	"	103	5.8	0 / 88 †	0	210
" 15.....	10.00AM	"	97	4.6	0 / 80 †	0	300
" 15.....	5.00PM	"	85	3.0	0 / 78 †	0	600
" 16.....	1.00AM	"	103	3.8	0 / 91 †	0	250
" 16.....	6.00AM	"	104	3.2	0 / 82 †	0	275
" 16.....	11.00AM	"	119	2.8	0 / 82 †	0	250
" 16.....	5.00PM	"	92	1.8	0 / 69 †	0	350
" 16.....	12.00PM	"	100	2.2	0 / 77 †	0	325
" 17.....	4.30AM	"	100	2.1	0 / 88 †	0	300
" 18.....	4.30AM	"	79	*	...	0	1,000
" 18.....	7.30AM	"	71	*	...	1	900
" 18.....	9.44AM	W-1	94	*	...	13	18,800
" 18.....	10.14AM	W-2	94	*	...	1	4,000

* Not indicated by gage. † Total alkalinity.

TABLE No. 8 — *Results of the Examination of the Effluent of the Polarite Filter* — (Concluded).

Collection of Samples.		Designation.	Rate of Filtration.	Loss of Head. Feet.	Parts per Million.		Bacteria per Cubic Centimeter.
Date—1899.	Hour.				Excess of Lime.	Suspended Matter.	
April 18	10.25AM	W-3	94	*	...	0	1,800
" 18	10.48AM	W-4	94	*	...	0	1,400
" 18	4.00PM	R	91	*	3	0	800
" 18	10.00PM	"	75	*	3	0	600
" 19	3.00AM	"	83	*	3	0	650
" 19	9.00AM	"	86	*	0 78 †	0	900
" 19	2.30PM	"	91	5.7	3	0	950
" 19	9.00PM	"	98	6.3	5	0	850
" 20	2.00AM	"	97	5.7	3	0	900
" 20	8.00AM	"	92	5.5	0 67 †	0	950
" 20	4.00PM	"	95	4.4	0 49 †	0	750
" 20	10.00PM	"	87	5.1	3	0	3,700
" 21	3.00AM	"	98	5.0	1	0	1,500
" 21	8.00AM	"	96	5.0	3	0	800
" 21	1.00PM	"	89	3.8	1	0	900
" 21	8.00PM	"	102	3.9	...	0	1,000
" 22	1.00AM	"	100	3.5	0 49 †	0	2,100
" 22	8.00AM	"	99	3.5	0 50 †	0	750
" 22	2.00PM	"	96	3.3	0 53 †	0	500
" 22	9.00PM	"	97	3.2	0 57 †	0	2,000
" 23	3.00AM	"	97	3.4	0 53 †	0	750
" 23	11.00AM	"	100	3.3	0 59 †	0	750
" 23	4.00PM	"	98	3.3	0 68 †	0	850
" 23	11.00PM	"	99	3.3	0 56 †	0	1,300
" 24	3.00AM	"	101	3.4	0 56 †	0	850
" 24	8.00AM	"	100	3.5	0 52 †	0	750
" 24	1.00PM	"	97	3.4	0 56 †	0	650
" 24	9.00PM	"	101	3.5	0 57 †	0	750
" 25	3.00AM	"	102	3.6	0 56 †	0	1,000
" 25	9.00AM	"	97	3.6	0 56 †	0	950
" 25	1.00PM	"	100	3.7	0 45 †	0	600
" 25	5.00PM	"	89	3.7	0 48 †	0	1,600

* Not indicated by gage. † Total alkalinity.

TABLE NO. 9—*Results of Chemical Analyses of Effluent of the Sand Filter.*

PARTS PER MILLION.

DATE. 1899	Oxygen consumed.	NITROGEN AS				ALKALINITY Caustic (CaO).		Total Residue on Evaporation.	Suspended Matter.
		Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.	Average.	Total ($CaCO_3$).		
March 13, 14.....	1.6	.056	.022	.000	0.82	77	145	141	0
" 15, 16.....	1.2	.044	.014	.000	0.82	78	137	143	0
" 17, 18.....	1.0	.036	.010	.000	0.90	59	105	122	0
" 19, 20.....	1.3	.050	.008	.000	0.86	36	75	121	1
" 21, 22.....	1.3	.042	.006	.000	0.62	41	80	111	1
" 23, 24.....	1.7	.060	.004	.000	0.54	41	72	103	3
" 25, 26.....	1.5	.060	.006	.000	0.66	36	70	102	1
" 27, 28.....	1.8	.088	.018	.000	0.86	32	60	104	3
" 29, 30.....	2.0	.084	.008	.000	0.90	32	65	109	2
" 31, April 1...	2.2	.080	.010	.000	0.58	56	100	126	30
April 2, 3.....	1.7	.046	.004	.000	0.74	39	75	102	3
" 4, 5.....	1.5	.046	.004	.000	0.74	39	100	76	1
" 6, 7.....	1.4	.042	.000	.000	0.94	0	120	198	1
" 8, 9.....	1.7	.038	.002	.000	0.70	0	90	164	3
" 10, 11.....	1.4	.042	.004	.000	0.74	0	98	162	1
" 12, 13.....	1.1	.082	.002	.000	0.54	36	64	88	0
" 14, 16.....	0.8	.026	.002	.000	0.70	47	84	102	0
" 18, 19.....	1.8	.046	.006	.000	0.66	37	66	78	0
" 20, 21.....	0.8	.044	.006	.000	0.62	26	51	89	0
" 22, 23.....	0 9	.034	.004	.000	0.46	28	50	84	0
" 24, 25.....	1.0	.038	.006	.000	0.62	22	41	77	0

TABLE No. 10—*Results of Chemical Analyses of Effluent of the Polarite Filter.*

PARTS PER MILLION.

DATE. 1899.	Oxygen consumed.	NITROGEN AS				ALKALINITY Caustic (CaO).		Sulphuric Acid.	Total Residue on Evaporation.	Suspended Matter.	Dissolved Oxygen.
		Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrares-	Average.	Total ($CaCO_3$).				
March 13, 14.....	1.3	.054	.016	.000	0.94	70	135	21	126	0	11.3
" 15, 16.....	1.2	.044	.016	.000	0.82	71	135	22	148	0	.....
" 17, 18.....	0.9	.036	.014	.000	0.90	56	100	28	128	0	.....
" 19, 20.....	1.3	.044	.008	.000	0.86	35	70	24	99	0	11.5
" 21, 22.....	1.3	.034	.004	.000	0.62	39	70	26	129	0	.....
" 23, 24.....	1.9	.050	.004	.000	0.62	35	65	24	99	1	.....
" 25, 26.....	1.6	.052	.004	.000	0.66	35	70	24	100	0	.....
" 27, 28.....	1.9	.068	.008	.000	0.86	31	55	24	104	1	10.2
" 29, 30.....	1.9	.076	.006	.000	0.86	32	56	26	99	4	.....
" 31, April 1...	1.9	.070	.008	000	0.46	45	85	22	109	10	.....
April 2, 3.....	1.7	.052	.004	.000	0.70	35	73	22	103	2	.....
" 4, 5.....	1.3	.044	.002	.000	0 86	22	106	24	110	1	11.1
" 6, 7.....	1.4	.040	.000	.000	0.94	6	105	12	175	0	.....
" 8, 9.....	1.5	.044	.002	.000	0.70	0	94	20	150	1	.....
" 10, 11.....	1.2	.038	.001	.000	0.74	0	94	12	157	0	.....
" 12, 13.....	1.1	.054	.002	.000	0.66	11	52	16	111	0	.....
" 14, 16.....	0.9	.022	.002	.000	0.18	0	80	16	138	0	.....
" 18, 19.....	0.7	.052	.004	.000	0.62	0	64	18	118	0	.....
" 20, 21.....	0.8	.040	.004	.000	0.62	0	48	18	112	0	.....
" 22, 23.....	0.8	.034	.002	.000	0.42	0	56	17	126	0	.....
" 24, 25.....	0.9	.038	.004	.000	0.62	0	49	18	106	0	.....

SECTION V.

Summary and Discussion of the Qualitative Efficiency of this System.

The efficiency of each portion or step of the process is first taken up in this section, and at the end the system as a whole is considered. The precipitation tank will receive attention first.

Efficiency of the Precipitation Tank in the Removal of Suspended Matter, Organic Matter, and Bacteria.

Based on the average results presented in Table No. 2 of Section IV, the efficiency of the precipitation tank during the official test was as shown in the following summary:

Constituent.	Parts per Million.		Percentage Removal.
	River Water.	Effluent.	
Suspended matter	273	35	87.2
Nitrogenous organic matter	0.236	0.078	66.9
Carbonaceous organic matter	5.7	2.0	64.9
Bacteria per cubic centimeter	23,800	1,300	94.5

During this test the total average period of subsidence was 15.8 hours, or 13.7 hours excluding the results for the first day; and the total amount of lime applied was equal to 4.7 grains per gallon of water.

Viewed by themselves, the above percentages of removal are very high; but in this system, when the effluent of the precipitation tank would be passed directly at all times on to the sand

filter, the amount and coagulation of the clay and suspended matters remaining in the effluent of the precipitation tank are the most important considerations from a practical standpoint, as noted below.

Coagulation and Amount of Remaining Suspended Matter as the Most Important Feature in the Effluent of the Precipitation Tank.

Inspection of the daily records in Table No. 2 of Section IV shows clearly that there was a well-defined relation between the efficiency of the entire system and the amount of suspended matter present in the effluent of the precipitation tank. These matters ranged from 10 to 104, and averaged 35 parts per million. Further inspection shows that on no occasion was the system operated to the best advantage when the amount of suspended matters in the water going on to the sand filter were materially in excess of about 25 parts per million. It is not probable that this limit in amount of suspended matters is the optimum for all grades of this river water, or that it corresponds uniformly to a proper degree of coagulation of the water at this stage in the process. In fact, with fairly clear river water, the limit would be somewhat lower. But for the range of river water treated during this test, 25 parts per million was apparently very close to the mark.

Comparing this limit with the actual daily amounts of suspended matter present in the effluent, it is seen that on this basis the precipitation tank did not yield satisfactory results for a number of days at a time, notably from March 19 to April 2, inclusive. During this period of fifteen days the actual average was 63 parts per million. These conditions resulted from efforts to determine the minimum quantity of applied lime. Viewed in this light, for the reasons given

above, it is seen that the efficiency of the precipitation tank as operated, while fairly satisfactory on an average, was not at all times as high as it should have been in order to have obtained the best practical results from the entire system.

Comparison of the Amount of Applied Lime with that Estimated to have been necessary for uniformly Satisfactory Results from the Precipitation Tank.

From the standpoint that the final effluent of this system should at all times be very low in bacteria, in order that the process should be operated to the best advantage, the amount of applied lime was somewhat too low. Computing the average rate of application of lime from the total amount of lime used and the total volume of water treated, the amount was 4.7 grains per gallon, although the average of the daily quantities used was 4.4 grains.

Taking as a guide the excess of lime in the effluent of this tank on those days (April 3 to 5) when the amount of suspended matter was approximately equal to the average amount for the total period, and correcting it for the average quantity of carbonic acid in the river water, it is estimated that it would have been necessary to have supplemented the average of 4.7 grains of lime per gallon by an average of about 1.5 grains, in order to have obtained uniformly from the tank an effluent of thoroughly satisfactory character.

Estimate of the Annual Average Amount of Required Lime.

As was clearly explained at the beginning of Section II, it is necessary in this system to apply lime water for two purposes:

1. To combine with the carbonic acid in the river water;
2. To provide an excess of lime to coagulate the water.

Relative to the first requirement, the evidence during the fairly normal year 1898 (see previous report) showed that on an average the Ohio River water at Cincinnati contained 26 parts per million of carbonic acid capable of combining with lime water. As one grain of lime (calcium oxide) per gallon, or 17.1 parts per million, combines with 13.5 parts per million of carbonic acid, it is clear that for this purpose substantially two grains of lime per gallon would be required for an annual average. A small fraction of one grain of lime per gallon would also be required for the conversion of magnesia salts to lime salts.

The question of estimating the excess of lime required to coagulate the river water properly is not so simple a matter. During these tests the excess of lime averaged 3.1 grains per gallon; and the average amount of suspended matter in the river water was 273 parts per million as compared with 230 parts, the average for the year 1898. While it is true that this amount of lime in excess enabled the sand filter to yield an average bacterial efficiency of about 99 per cent, yet on many days it was considerably below this and less than should be obtained in practice. It is also true that, with a system capable of maintaining uniformly a bacterial efficiency of about 99.8, there is no room for doubt from a hygienic point of view but that it would be wiser to go to the slightly greater expense of adding a small additional quantity of lime for the sake of the bacterial efficiency.

Taking every thing into consideration, it is estimated that on an annual average four grains of lime (calcium oxide) per gallon would be required in excess of that combining with the carbonic acid, in order to coagulate this river water properly with a 12-hour period for precipitation. Adding this to the

amount required to combine with the carbonic acid, there is obtained six grains per gallon as the total annual average. This would give a very satisfactory effluent under favorable conditions, except for the question of the disposition of the excess of lime, a matter which is taken up fully in the following paragraph.

Concerning the range in the applied lime, there would be necessary from 0.5 to 3.5 grains per gallon in order to combine with the carbonic acid, and to coagulate the water the excess would probably range from 1 to 7 grains per gallon. Combining the two, the range for the total applied lime would be approximately from 3 to 10 grains per gallon.

Effect of the Applied Lime upon the Dissolved Constituents of the Water treated by this System.

So far as relates to the effect in the precipitation tank, the applied lime makes no change in the following constituents:

Nitrogen as free ammonia;
Nitrogen as nitrites;
Nitrogen as nitrates;
Chlorine;
Sulphuric acid;
Dissolved oxygen.

It does affect the following constituents:

Dissolved organic matter (both nitrogenous and carbonaceous);
Carbonic acid;
Incrusting constituents (not quantitatively);
Alkalinity.

The effect of the applied lime upon each of the last-named constituents as they appear in the effluent of the precipitation tank is taken up in turn, as follows:

Dissolved Organic Matter.— As is the case with all efficient coagulants, the applied lime causes the removal of all unstable dissolved organic matter, and reduces it to a residual quantity of such stable character that it can be ignored, practically speaking. The evidence shows that during this official test the dissolved nitrogenous organic matter in the river water, equal to .061 part per million of nitrogen as albuminoid ammonia, was reduced to about .051 part as the water left the precipitation tank. This latter figure probably represents approximately the nitrogen of the residual stable organic matter referred to above.

Carbonic Acid.— Practically all, if not absolutely all, of the carbonic acid was removed from the water.

Incrusting Constituents.—The total amount of incrusting constituents, chiefly the sulphate and chlorides of lime and magnesia, is not affected by the lime treatment. But in exact terms there would probably be an interchange between the sulphate and chloride of magnesia and the added lime, resulting in the formation of sulphate and chloride of lime and the removal of the magnesia. Practically speaking, the significance of this is very small indeed.

Alkalinity.—The bicarbonates of lime and magnesia (temporary hardness) are completely removed by the applied lime; the effluent of the precipitation tank was found to contain only a very small amount of the normal carbonates of these bases, the average being about three parts per million.

While the natural alkalinity of the river water is practically all removed by this process, there is added a caustic alkalinity

due to the excess of lime water necessary for coagulation. The amount of this caustic (lime water) alkalinity would vary much from time to time, according to the composition of the river water, and would range apparently from 1 to 7 grains of calcium oxide, as pointed out under the preceding topic. Expressing this lime-water alkalinity in its equivalent amounts of the conventional carbonate of lime, the added lime would range from 1.8 to 12.3 grains per gallon.

The significance of this excess of added lime water is one of the most important considerations in connection with the practicability of this process, and is taken up at length in this section just after the discussion of the efficiency of the filters.

Effect of the Period of Subsidence upon the Efficiency of the Precipitation Tank in the Removal of Suspended Matters and Bacteria.

In Table No. 5 of Section IV there were presented the results of fifteen special tests of the water drawn from time to time from the several taps located at different levels on the precipitation tank. A summary of those data is as follows:

Hours of Subsidence.	Suspended Matter. Parts per Million.	Bacteria per Cubic Centimeter.	Percentage Removal.	
			Suspended Matter.	Bacteria.
0.0	258	21,700	0.0	0.0
4.5	80	2,800	69.0	87.1
6.2	65	2,300	74.8	89.4
7.8	53	1,500	79.5	93.1
9.9	41	950	84.1	95.6
12.0	38	1,600	85.3	92.6

These data are presented as a matter of record, and indicate that 12 hours was very close to the economical limit in the period of subsidence by this process with the amount of lime employed. It will be noted that the bacterial results are somewhat irregular, due evidently to difficulties in separating the individual bacterial cells in the floccules or flakes.

Efficiency of the Sand Filter.

Attention is next given to the effluent of the sand filter, to which was applied the coagulated effluent of the precipitation tank.

Appearance.—Normally this effluent was clear or brilliant and perfectly satisfactory in appearance. Directly after washing or agitating, it deteriorated very noticeably for a few minutes on many occasions. But practically this would not be a serious matter, because on such occasions the effluent of the particular filter, being washed or agitated, would be diluted by the effluent of all the other filters.

At times this effluent was slightly turbid, and it was unsatisfactorily so on March 31 and April 1. This was due solely to inadequate coagulation, and could be avoided in practice with efficient management.

Removal of Organic Matter.—The remaining organic matter in the effluent of the sand filter (1.4 parts of oxygen consumed and .051 part of nitrogen as albuminoid ammonia) was practically as low as it is possible to obtain by any process now known; and was so stable in character that it may be regarded as a perfectly satisfactory result.

Nitrification was not a practical factor in connection with this filter.

Bacterial Efficiency.—During the official test the bacteria in the effluent of the sand filter averaged 248 per cubic centimeter, corresponding to a bacterial efficiency of 99 for the system up to and including the sand filter. On a number of days the efficiency was materially less than this, and this was due to the inadequate coagulation of the water applied to the sand filter.

On the other hand, there were 13 days out of the total 44 days when the efficiency was 99.8 or more. With adequate coagulation, such as would be assured with an annual average application of six grains of lime per gallon, there is every reason to believe that an average bacterial efficiency of 99.8 could be maintained, and that on daily average it would fall appreciably below this very rarely, and possibly not at all.

Concerning the bacterial efficiency just after agitation or washing, there was a distinct deterioration; but from a practical standpoint it was not serious, as, similarly to the turbidity of the effluent after washing, it would be so diluted by the effluent of other filters that its effect would be practically disguised.

In the following tables are summaries of the special bacterial examinations of the effluent just after washing and agitation. They are prepared from averages of all results after agitation, and all results after washing up to April 19, as given in detail in Table No. 7 of Section IV. Beginning on April 19, the results after washing were distorted by the bacterial growths which occurred in the wash-water tank, as the results of several examinations showed that the wash water contained over 50,000 bacteria per cubic centimeter. For the bacterial efficiencies the average number of bacteria in the river water was used in all cases.

Summary of the Results of Special Bacterial Analysis to show the Effect of Washing and of Agitation.

WASHING.

Deignation of Sample in Table No. 7.	Average Time after Opening Outlet. Minutes.	Quantity of Effluent Passed after Opening Outlet. Cubic Feet.	Million Gall'ns per Acre.	Bacteria per Cubic Centimeter.	Bacterial Efficiency.
W-1	4	100	0.30	750	96.8
W-2	11	250	0.75	500	97.9
W-3	22	500	1.50	325	98.6
W-4	44	1,000	3.00	300	98.7

AGITATION.

A-1	4	100	30.0	650	97.3
A-2	11	250	0.75	210	99.1
A-3	22	500	1.50	190	99.2
A-4	44	1,000	3.00	170	99.3

If the effluent of the precipitation tank had been uniformly coagulated to a suitable degree, the increases in the number of bacteria under the condition in question would have been very much less, as it will appear from inspection of the detailed data in Table No. 7.

Effect upon the Excess of Lime.—On those occasions when no effort was made to remove the excess of lime by the application of carbonic acid, prior to the filtration through the sand filter, it was found that there was a slight reduction in the excess of lime, apparently due to the action of the sand layer. On an average this amounted to 0.4 grain per gallon, which, while it was appreciable, was obviously almost *nil* from a practical standpoint.

Efficiency of Polarite Filter.

Inspection of the evidence as summarized in Table No. 2 of Section IV shows clearly the following points:

1. On those occasions when there was proper coagulation of the effluent of the precipitation tank there was no substantial improvement of the effluent of the sand filter after its passage through the polarite filter (independent of the application of carbonic acid). In fact, there was a deterioration bacterially during the last week, but this apparently was largely due to temporary conditions.

2. When the coagulation of the effluent of the precipitation tank was inadequate to allow the sand filter to yield a satisfactory effluent (independent of the excess of lime) the polarite filter clearly showed its inability to remedy matters.

Taking every thing into consideration, it may be safely concluded that the polarite filter was a superfluous portion of this system of purification, independent of the question of the removal of the excess of lime. Further, if the removal of the excess of lime should involve a secondary filtration, it should be accomplished by a sand filter in order to save the expense of the more costly polarite.

Necessity of removing Excess of Lime in the Final Effluent.— A series of tests was undertaken to show the solvent action upon iron, brass, tin, copper, and lead of filtered water containing lime in excess (1 to 3 grains per gallon) in quantities which were actually present in the final effluent during a large portion of these tests. The results of these special tests, which are in strict accord with the available literature upon the subject, showed that there was no well-defined solvent action in the case of iron, brass, tin, or copper, although there seemed

to be some indications that the iron rusted a little more quickly than when placed in ordinary local river water. But with lead the results were very different. With an excess of one grain of lime (CaO) per gallon, the solvent action of the filtered water upon lead, even upon standing in contact for only 12 hours, was quite pronounced. With greater quantities of lime in excess the solvent action was greater and more rapid.

In the case of the untreated Ohio river water there is a pronounced solvent action upon lead. But very quickly the carbonate and bicarbonate of lime form a basic carbonate of lead upon the surface of the pipe, which is impervious and serves as a thorough protective coating against further action.

Due to the nature of this process of purification, the applied lime water removes practically all of the carbonates of lime in the river water, which gives to lead pipes a protective coating. Not only that, but the excess of lime water, which it is necessary to employ, evidently gives to the water a greater solvent action on lead than is possessed by the river water after removing the carbonates of lime.

As lead service-pipes are quite generally employed in this city, and as lead in solution (as is well known) is a cumulative poison, it is imperative that, independent of other reasons, the final effluent of this system should be free from an excess of lime; and furthermore, to render the use of the filtered water perfectly safe in lead pipes, it should contain a certain amount of lime in solution in the form of carbonate or bicarbonate. The amount of carbonated lime which would serve as a protective coating for lead pipes, so far as our knowledge goes, is about one grain per gallon for a minimum.

Description and Discussion of the Evidence obtained with Reference to the Removal of the Excess of Lime.

The inadmissibility of having an excess of lime in the final effluent was clearly appreciated by the gentlemen in charge of the operation of this plant, and during the last three weeks of the test steps were taken with the view to its removal uniformly by an application of carbonic acid. This general step was well advised, but it involved a number of important features and practical details which had not been worked out at the beginning of the test, and which in a measure were not satisfactorily solved at the close of this test.

In practice it is said that carbonic acid would be obtained from limekiln gases, from the limestone burnt at the plant; but here that was not practicable, and it was necessary to use liquefied carbonic acid, obtained in holders containing about 50 pounds each, and from which about 40 pounds or a little more could be removed. The available appliances for controlling the application of the gas were very unsatisfactory at first, but were improved more or less from time to time.

A detailed outline of the evidence obtained from the application of carbonic acid during this test is next presented.

Impracticability of applying Carbonic Acid to the Untreated River Water to avoid an Excess of Lime in the Effluent.

The application of carbonic acid to the river water at a connection on the inlet pipe just as it left the ground beneath the precipitation tank was begun on March 30, at 9:30 A. M. Owing to difficulties in the control of the gas, the application was more or less irregular, and at times none was applied during the period ending on April 1, at 8:40 A. M. For this

reason the records of the quantity of carbonic acid applied are so inadequate as to be of but little value; but it is sufficient to state that during the afternoon and night of March 31 the quantity applied was such that the excess of lime in the effluent of the precipitation tank was reduced to about one grain per gallon. When this water reached the filters they failed very quickly, both of them giving a brownish effluent, and with 4,500 and 3,100 bacteria per cubic centimeter in the effluents of the sand filter and polarite filter, respectively.

The plant was promptly shut down upon the arrival of Mr. MacDougall, and the precipitation tank was drained and refilled with river water, to which was added an adequate excess of lime water. This explains the delay from April 1 (8:40 A. M.) to April 2 (5:02 A. M.) During this interval the carbonic-acid appliances were disconnected from the river-water pipe, and attached to the mouth of the pipe conducting the effluent of the precipitation tank on to the sand filter. The carbonic-acid pipe (about 0.25 inch in diameter) passed through the ell on the end of this vertical pipe, and extended into it about six inches.

While this procedure caused a failure in the quality of the effluent and necessitated a considerable delay, the information obtained is very valuable in that it adds substantial confirmation to less comprehensive observations in explanation of the manner in which the lime water accomplishes its work.

The explanation of this experience is readily apparent from the manner in which the applied lime affects the coagulation of the suspended matters in the water, as described at the beginning of Section II.

Returning to the main topic under discussion, the evidence is decisive that it is impracticable to apply carbonic acid to the original river water with the view to preventing an excess of lime water in the final effluent.

Questionable Practicability of applying Carbonic Acid to the Effluent of the Precipitation Tank as it enters the Sand Filter to remove the Excess of Lime in the Effluent.

During the period from April 2 (5:55 A. M.) to April 12 (8:35 A. M.) carbonic acid was applied, with a few interruptions, to the mouth of the inlet pipe in the sand filter just described.

The average quantity of applied lime (CaO) in this period was 4.8 grains per gallon, giving an excess of 3.8 grains in the effluent of the precipitation tank. The remaining one grain per gallon was utilized in combining with the carbonic acid naturally present in the river water.

To combine with this 3.8 grains per gallon of lime water in excess there were required 3.0 grains per gallon of carbonic acid, and to obtain one grain per gallon of bicarbonate of lime in the effluent there were required 3.4 grains per gallon of carbonic acid.

There were applied to the water during this period 1,387 pounds of carbonic acid, equal to 4.0 grains per gallon on an average. As an average quantity, the application was reasonably satisfactory; but the range of application, from 0 to over 10 grains per gallon, was so irregular that it did not uniformly produce the desired result, and clearly showed that the question of arranging and controlling the application of carbonic acid must receive further attention. Independent of the wastage of about 25 per cent of carbonic acid by remaining in the holders, there was also a considerable wastage when the rate of application was high, due to the bubbles of carbonic-acid gas rising to the surface of the water, and allowing no benefit to be received from the gas in the interior of the bubbles.

As a result of this irregular application of carbonic acid, the

composition of the final effluent was naturally very variable as to the lime which it contained. This is shown in Table No. 7 of Section IV, where it is seen that the excess of lime in some cases was not reduced materially, if at all, and in other instances there was no excess of lime (CaO), and the lime in the effluent was present as the bicarbonate to the extent of 10 grains per gallon (170 parts per million) and more. In those cases where there was no lime present it will be noted, as has already been explained, that in the table under the column "Excess of lime," there are two figures given in a bracket. The upper one in all cases refers to lime, and the lower one refers to the total alkalinity which was due almost entirely to the bicarbonate of lime.

From a practical standpoint the question of applying carbonic acid in too great amounts is one of great significance, because it is possible at times to dissolve so much lime (stored in the filter as insoluble carbonate) in the form of bicarbonate as to make the effluent unfit for domestic and manufacturing purposes: that is to say, if for 23 hours per day the rate of application of carbonic acid was satisfactory, and the excess of lime was removed as insoluble carbonate (except one grain per gallon of bicarbonate); and then if for one hour per day the carbonic acid was applied in excessive amounts, it could dissolve enough lime stored in the filter to make the effluent decidedly unsatisfactory.

Disregarding the question of the irregular manner of applying the carbonic acid, the application of the gas at the influent to the first filter was not thoroughly satisfactory, because it was found that the removal of the excess of lime at this point in a measure undid the effect of the excess of lime water, and seemed to break up in part the aggregated masses of clay and bacteria. The available evidence points very clearly in that

direction; and while the quality of the effluent from April 2 to 12 was fairly satisfactory on some occasions independent of the excess of lime, there are good reasons for believing that a very much better effluent, with regard to removal of bacteria and clay, would have been obtained had not the carbonic acid been applied prior to the first filtration.

Theoretically there is no room for doubt but that this is not the best place to apply the carbonic acid. Practically, however, it is to be remembered that with favorable conditions for the application of carbonic acid the effluent can be maintained apparently in a fairly satisfactory degree of purity, and that to apply the carbonic acid to the effluent of the sand filter means that locally, at least, it would be necessary to employ a second filtration solely to remove the precipitated carbonate of lime.

Taking every thing into consideration, it may be stated that, while the problem was not worked out to as fine a point as would be desirable, the evidence points clearly to the inadvisability of applying the carbonic acid at this point, in order to allow the system to be operated to the best advantage.

Application of Carbonic Acid to the Effluent of the Sand Filter in order to remove the Excess of Lime.

From April 13 to the close of the test carbonic acid was applied in a closed cask to the effluent of the sand filter, and before the water was passed through the polarite filter, as has been previously described in Sections II and III.

The evidence in Table No. 8 of Section IV shows the application of the carbonic acid, and was not under satisfactory control because the effluent of the polarite filter either contained some excess of lime or else all of the lime passed through in the form of the bicarbonate. It so happened that

the river water was fairly clear at this time, and the lime in excess was comparatively low. Nevertheless it showed a marked weakness of the process as operated, because during freshets in the river it would not be admissible to pass all the excess of lime into the final effluent as the bicarbonate.

It appears that this is the best stage in the process to apply the carbonic acid; but the test came to a close without showing satisfactory evidence upon the following important points:

1. Control of the rate of application of the carbonic acid.

2. The most practicable way in which to secure a thorough mixing of the carbonic acid and the water.

3. The period of time which should intervene between the application of the gas and the entrance of the water into the second filter.

This general proposition of applying carbonic acid to remove the excess of lime is a practicable one from a theoretical standpoint, as was shown by laboratory experiments in which a thorough intermingling of the gas and the water was obtained. To accomplish this satisfactorily in practice with this system of purification is imperative, and it involves a number of important details as noted above.

From the actual evidence obtained during this test there is nothing more to be said upon the subject. It is referred to again, however, in the next section, in connection with the cost of the devices which the Engineering Company propose to adopt in practice in connection with limekiln gases.

Relation of Proper Attention and Supervision to the Efficiency of this System.

In a system of purification in which it would be necessary to make a double application of chemicals to the water constantly, it goes without saying that it must be operated under

skilled supervision and with an adequate number of trained attendants. This is true not only for the sake of maintaining a final effluent of satisfactory character, but also for the sake of economy.

Final Conclusions.

Summing up the evidence upon the efficiency of this system of purification, the following conclusions may be drawn:

1. When lime water in suitable excess is applied to the water, subsidence for about 12 hours in a precipitation tank and rapid filtration through a sand filter produces, with efficient management, an effluent which is very satisfactory in appearance and in its contents of organic matter and bacteria, but which is not safe for domestic use owing to the excess of lime water.

2. The polarite filter is a superfluous part of the system as originally designed.

3. It is imperative to remove the excess of lime from the final effluent, and this can be satisfactorily accomplished apparently by the application of carbonic-acid gas.

4. It is impracticable to apply the carbonic acid to the untreated river water, and apparently this is also true with reference to its application at the inlet to the sand (first) filter.

5. The best place to apply the carbonic acid is to the effluent of the sand filter, and prior to a second filtration.

6. For the second fillration a sand filter would be equally as efficient as the more expensive polarite filter.

7. There are a number of important practical details concerning the application of carbonic acid which were not satisfactorily solved during the period of the official test, but which, from a theoretical standpoint, appear to be capable of solution.

SECTION VI.

SUMMARY OF ACTUAL DATA, SUPPLEMENTED BY ESTIMATES AND DISCUSSION, OF THE COST OF PURIFICATION BY THIS SYSTEM.

An outline of the elements of cost of purification by this system, both of construction and of operation, will be presented in compliance with the instructions of January 17 and 27, 1899, and supplemented by the available evidence on each of the more important points, as follows:

A—*Elements of Cost of Construction.*

1. Pipe-line connections to the force mains.

2. Mixing tower in which to mix the river water and lime water.

3. Lime plant, including kilns, scrubbers, mixers, solution tanks, pumps, and pipe lines between the river-water pipes, solution tanks, and the mixing tower, and also a house with storage room covering the entire lime plant.

4. Precipitation tanks with foundations and house, and including piping from the mixing tower and to the filters, and to the sewer.

5. Filter plant complete, including two sets of filters, with an intermediate arrangement for the application of carbonic-acid gas, foundations, filter house with proper heating and lighting, all piping and fittings within the filter house, and necessary appurtenances for agitating and washing the filters.

6. Power plant, including a house, agitating engines, wash-water pumps, carbonic-acid gas compressors, dynamo for lighting, and boilers.

7. Clear well, with all piping outside the filter house to discharge the filtered water into a gravity conduit leading to the city, and a main sewer for the removal of the wash water from the filters and the sediment from the precipitation tanks and the lime-solution tanks.

8. Office and laboratory building, with a suitable equipment.

B—*Elements of Cost of Operation.*

1. Supplies, consisting principally of unburnt limestone, coke, coal, and filtered water (for washing).

2. Skilled supervision to direct constantly the management of the plant.

3. Analysts and assistants to collect and record the evidence necessary for the efficient and economical operation of the plant.

4. Mechanics, engineers, and foremen to operate the necessary machinery.

5. Attendants (intelligent and trustworthy laborers) to operate the limekilns, lime-mixers, lime-solution tanks, precipitation tanks, filters, and carbonic-acid appliances.

6. Special labor, as required, to handle lime and to assist in operating the plant during freezing weather.

7. Repairs and replacement of machinery and the less durable appliances.

8. General repairs.

As was the case in the previous report upon the systems investigated last year, 80 million gallons is taken as the daily capacity of a plant required for this water supply. The prin-

cipal data upon the foregoing elements of cost are next taken up in brief terms, as follows:

Pipe Line to Force Mains.—This would be a double line of 60-inch cast-iron pipe, having a total combined length of about 1,644 feet.

Mixing Tower.—In place of the circumferential mixing gutter at the top of each precipitation tank, it is proposed by the Engineering Company to have a mixing tower (in duplicate) at such an elevation that the mixed river water and lime water would flow to the several precipitation tanks. The capacity of the tower has not been definitely settled; but, judging from the size of the mixing gutter, it ought to hold at least from three to five minutes' flow.

Limekilns.—On the basis of a maximum application of 10 grains of quicklime (CaO) per gallon (see Section III), there would be required about 60 tons of quicklime per day. As it takes practically two tons of the best available limestone to make one ton of quicklime (calcium oxide), the limekiln should have a maximum capacity of about 120 tons of limestone per day. At times not more than 30 per cent of this amount would be needed, and the average would be about 65 per cent. But, as it takes several days to get a limekiln in operation, it would be necessary during times of fairly clear river water to produce more lime than would be required, in order to have sufficient carbonic acid to treat satisfactorily the muddy water coming from sudden rises in the river.

As a rule, there would be a considerable wastage of carbonic-acid gas. The occasional surplus of lime, however, could probably be sold to fair advantage. This would be cheaper than efforts to store carbonic acid in sufficient amounts to deal with the muddy water of sudden freshets.

Volume of Lime Water.—With saturated lime water containing on an average 64 grains of calcium oxide per gallon, and with the range and average rate of application, as stated above, the maximum, minimum, and average quantity of required lime water for an 80-million-gallon plant would be 12.5, 3.75, and 8.1 million gallons daily. The river water used for preparing the lime water would have to be diverted from the force mains into the lime-water tanks.

Capacity of Lime Tanks.—The combined capacity of these tanks should be such that the period between the use of successive lots (tankfuls) of lime water from the same tank would allow refilling, and also an opportunity for the solution to become fairly clear by subsidence when the river water is very muddy. This period is estimated at about six hours.

Elevation of Lime Water.—For the purpose of keeping the application of lime water under good control, it seems wisest to operate the lime-water tanks on the fill-and-draw plan, and pump the solution into a mixing tower. On an average, the lime water would probably have to be elevated about 15 feet.

Precipitation Tanks.—During the official test the period of subsidence was normally 12 hours, corresponding to a total capacity of 40 million gallons for the precipitation tanks, on the size of plant under consideration.

It is claimed by the Engineering Company this period could be safely reduced to 8 hours. This is doubtless true; but for the sake of maintaining at times of freshets in the river an effluent from the precipitation tanks which would be properly clarified and coagulated, the evidence indicates that it would be necessary to add lime at a somewhat greater rate than with a period of 12 hours for subsidence, as already noted. While the data are not as decisive upon this point as desirable (see Table No. 5, Section IV), they indicate that it would be per-

fectly safe to employ an 8-hour period of subsidence (precipitation tanks having an available capacity of 27 million gallons) and an annual average of 6.5 grains of lime per gallon, instead of 12 hours and 6.0 grains.

Protection from Freezing.—Although it might be possible with extra labor to operate the uncovered precipitation tanks during winter weather at a less cost than would be involved in housing them, yet the former procedure would be hazardous on account of the uncertainty in securing sufficient extra labor when their use would be imperative for the maintenance of the city's water supply. For this reason it is considered necessary to place the precipitation tanks under cover.

Filters.—Two sets of filters would be required according to present evidence, one set to be placed above the other. The rate of filtration in each case would be 100 million gallons per acre daily, according to the actual data, and a 10 per cent reserve would be provided to compensate for filters out of service for washing or repairs. However, there seems to be no reason why a rate of 125 million gallons per acre daily could not be safely used, as was the case with the American filter tested by the city from September, 1898, to January, 1899. All filters would contain layers of sand only—probably three feet thick. The washing and agitating devices would be arranged similarly to those in the sand filters, as described in Section III.

Carbonic-acid Mixers.—As was explained in the last section, it is necessary to apply to the effluent of the first filter a quantity of carbonic acid capable of neutralizing the excess of lime. On a large scale the Engineering Company propose to accomplish this with kiln gases

The manner in which the gases would be uniformly applied to the water is a question not yet definitely settled by the Engineering Company, so far as I know. It is said that it would

probably be done in a series of closed compartments, into which the water would be introduced at the top and the kiln gases at the bottom, and which would be furnished with agitating appliances to facilitate the mixing of the water and gases.

Power Appliances.—The power plant, as already mentioned, would include the following:

1. Lime-water pumps;
2. Agitator engines;
3. Wash-water pumps;
4. Carbonic-acid appliances;
5. Dynamos for lighting;
6. Power for elevators for handling lime;
7. Boilers to furnish steam for the above, and also for heating the various buildings.

Clear Well.—As in the estimates of the previous report, this is taken as an open reservoir of 20 million gallons capacity, and all necessary piping connections outside the filter house.

Estimated Cost of Construction of an 80-million-gallon Plant of this Process.

No detailed plans have been completed for a plant representing this system of purification, and therefore all estimates of cost must be regarded as provisional approximations for the purpose of comparison only, and not exact figures. This is especially true, owing to the present indefiniteness attached to certain portions of the plant, as already stated.

At the request of the writer, the Ohio Sanitary Engineering Company made an estimate of $2,000,000 as the approximate cost of a plant having a capacity of 80 million gallons per day. As instructed by you, I have prepared and submitted approximate estimates of cost, and found that the above sum would be inadequate for a plant of this size on a basis of 12 hours for

subsidence in the precipitation tank and for a rate of filtration of 100 million gallons per acre daily. But with a period of 8 hours for subsidence and a rate of filtration of 125 million gallons per acre daily, as was apparently the basis of the Engineering Company's estimate, $2,000,000 is a fair figure, and would provide suitable houses for the entire plant, excluding the clear well. As already explained, the last stated basis of estimation would be satisfactory provided a sufficient amount of chemical was used.

Within reasonable limits this estimate of $25,000 per one million gallons of rated capacity per day would provide a grade of construction comparable to that estimated for the systems reported upon in January, 1899, except, of course, that in the present one the ratio of metal to masonry is far greater. It is to be noted, however, that current prices, as a rule, are considerably higher than they were in January. As in the earlier estimates, no provision is made for the cost of land which is now owned by the city.

Taking the fixed capital charges at 5 per cent per annum, this would cover interest charges, which would be something less than 3.5 per cent; and it would provide a sinking fund of about 1.5 per cent. The object of the sinking fund would be the redemption of the bonds covering the original cost of construction, as is the current custom, and also perhaps some slight incidentals which are too insignificant to place in the present estimates of operation. With good investment the sinking fund should redeem the bonds in 35 years.

With the above estimate, the annual fixed charges at 5 per cent would be $100,000, which for an 80-million-gallon plant corresponds to a fixed capital charge of $3.42 per million gallons.

Cost of Lime and Carbonic Acid.

The cost of lime (calcium oxide) per ton is estimated by the Engineering Company at four dollars, exclusive of capital charges and repairs on the lime plant. This figure covers the broken limestone delivered on the ground at the plant, coke, and labor in operating the kilns. The labor would call for ten men per day, without removing the lime to mixers or storerooms, after drawing it from the kilns. The carbonic acid in the kiln gases would be a by-product.

The above figure appears to be a very close one on present quotations and would necessitate the sale of some surplus (rich) lime at four dollars per ton. The quotations obtained on the broken limestone laid down on the ground at the plant were high ($1.50 per ton), and undoubtedly it would be possible to secure freight rates which would reduce this somewhat. On the whole, it is considered that four dollars per ton for lime, with carbonic acid as a by-product, is a fair price.

On the basis of an 8-hour period of subsidence, it is estimated that as an annual average 6.5 grains of lime (calcium oxide) would be required per gallon of filtered water. This would make the cost of lime and carbonic acid amount on an average to $1.86 per million gallons.

Coal.

It is estimated that on an average eight tons of coal per day would be required to furnish steam for the operation of the necessary machinery, and including the heating and lighting plants. At two dollars per ton delivered at the plant, the cost of coal on this basis would amount to twenty cents per million gallons.

Wash Water.

During the official test the wash water amounted to 1.36 per cent of the water filtered. This did not include, however, a sufficient quantity of water for cleaning the precipitation tank, and the amount of carbonate of lime washed from the second filter was very small. It is believed that 2 per cent on an average would be a sufficient quantity of water to wash the devices. Although some of the water used for cleaning the first filter was not filtered, it caused a delay in operations so that its cost was practically the same.

The cost of this water represents not only the cost of purification, but also the cost of delivering the water to the purification works. In round numbers this cost would be fifteen dollars per million gallons, the same as was used in the earlier estimates. On this basis the cost of wash water would be thirty cents per million gallons.

Supervision and Attendance.

This system of purification, like all others, would have to be well managed in order to be efficient; and there are strong reasons for believing that in this case efficient management would be the cheapest in the long run.

The following estimate for an 80-million-gallon plant includes all labor which would be required, exclusive of the operation of the limekilns: that is to say, the lime has been previously provided for up to the point of its having been drawn from the kilns. So far as possible this estimate is made on a comparable basis to that made for the American system, as reported upon on January 31, 1899. This estimate excludes the three attendants for the subsiding reservoirs, which would not be used in this system as at present considered, but includes

thirteen more attendants. The distribution of these extra attendants would be substantially as follows: One man per day to clean and regulate the precipitation tanks; one man per watch on the preparation of lime solutions; one man per watch to help the engineer, who would have carbonic-acid compressors to operate; two men per watch to operate filters (double in number) and carbonic-acid mixers.

The total list, with estimates of cost on the basis of current wages paid by the city to skilled and unskilled laborers, is as follows:

1 Superintendent	4,000 00	per annum
1 Assistant superintendent	2,400 00	"
2 Analysts	3,000 00	"
3 Assistants and clerks	1,800 00	"
1 Janitor	600 00	"
28 Attendants for filters, lime-water, and carbonic-acid devices	20,160 00	"
1 Machinist	1,440 00	"
3 Engineers	4,320 00	"
3 Firemen	2,160 00	"
Extra labor as required	1,500 00	"
Total	$41,380 00	per annum

On this basis the cost of supervision and attendance would amount to $1.42 per million gallons.

Repairs, Depreciation, and Replacement of Devices.

It is a difficult matter to make satisfactory estimates upon this point, owing to the absence of decisive data to serve as a guide. As already explained, a sinking fund is provided for the purpose of redeeming the bonds in about 35 years, according to the conventional practice in public work of paying for works within about one generation after their completion.

In a plant of this nature there are portions, such as buildings, masonry, and piping system, which would have a life

of 35 years or more, and in this connection require only a provision for repairs from time to time, estimated to be equivalent per annum to 0.5 per cent of the original cost. While some of the structures would doubtless have a life of more than 35 years, it is apparently not safe to count upon it, owing to uncertainties as to the utilization of this plant beyond this period.

On the other hand, there is a fairly large number of small devices and portions of structures in a plant of such a nature, such as the machinery, which would not only have a shorter life, but would also require a larger provision for repairs, due to their construction and the nature of the work which they would have to perform. Furthermore, it is certain that, with the first plants constructed for the purification of the local type of water, there will be portions of it which will become antiquated in a very short time. This is bound to be so with any system, as the practical operation of a large plant will yield experience which it is impossible to obtain from even long tests of small experimental plants, where the opportunity of testing the relative merits of different types of construction of important portions of the plant are small.

As in the case of the American System reported upon last January, there have been selected portions of the plant on this basis, made up of the following principal items: Lime-kilns and mixers; lime-water pumps; mixing tower; false bottoms and sand supports in filters; filter sand; agitators, belts, and pulleys; agitating engines; wash-water pumps; boilers; carbonic-acid compressors; carbonic-acid mixers; piping from mixers to second filters; and heating and lighting plants.

The estimated cost of these devices is $240,000, or $3,000 per million gallons. *On an average*, it is believed that 10 per

cent of original cost per annum is none too large to provide for repairs and replacement. This is equivalent to eighty-two cents per million gallons.

These remaining portions form an intermediate class, the steel precipitation tanks and the filter tanks, the life of which is not certain. But it surely would be short in the absence of timely repairs. While the life of metal in contact with ordinary water is not very accurately known, it is still less certain (but doubtless shorter) when subjected to the action of lime water, carbonic acid, and moving sand, as is the case during agitation in filters. Unquestionably the interior of these structures would require frequent painting, and it is doubtful whether a life of more than 20 years could be depended upon. To provide for painting and repairs, and also an extra fund which added to the regular sinking fund in 20 years would redeem the bonds representing the cost of these devices, would necessitate an annual charge estimated at 3 per cent of the original cost, which substantially would be $10,000 per million gallons. This is equivalent to eighty-two cents per million gallons.

Total Estimated Cost per Million Gallons Filtered Water by the System of the Ohio Sanitary Engineering Company.

Fixed capital charges on the cost of construction	3 42
Lime and carbonic acid	1 86
Coal	20
Wash water	30
Supervision and attendance	1 42
Repairs and replacement of machinery and devices (10 per cent per annum on $3,000)	82
Repairs and depreciation of precipitation tanks and filter tanks (3 per cent per annum on $10,000)	82
General repairs 0.5 per cent per annum on the remainder of the plant ($12,000)	16
	$9 00

Head required for the Operation of a Plant by this System.

As nearly as can be estimated, in the absence of complete plans, a plant by this system would require for its operation a head of about 25 feet.

Respectfully submitted,

GEORGE W. FULLER,
Chief Chemist and Bacteriologist.

CINCINNATI, OHIO, May 24, 1899.

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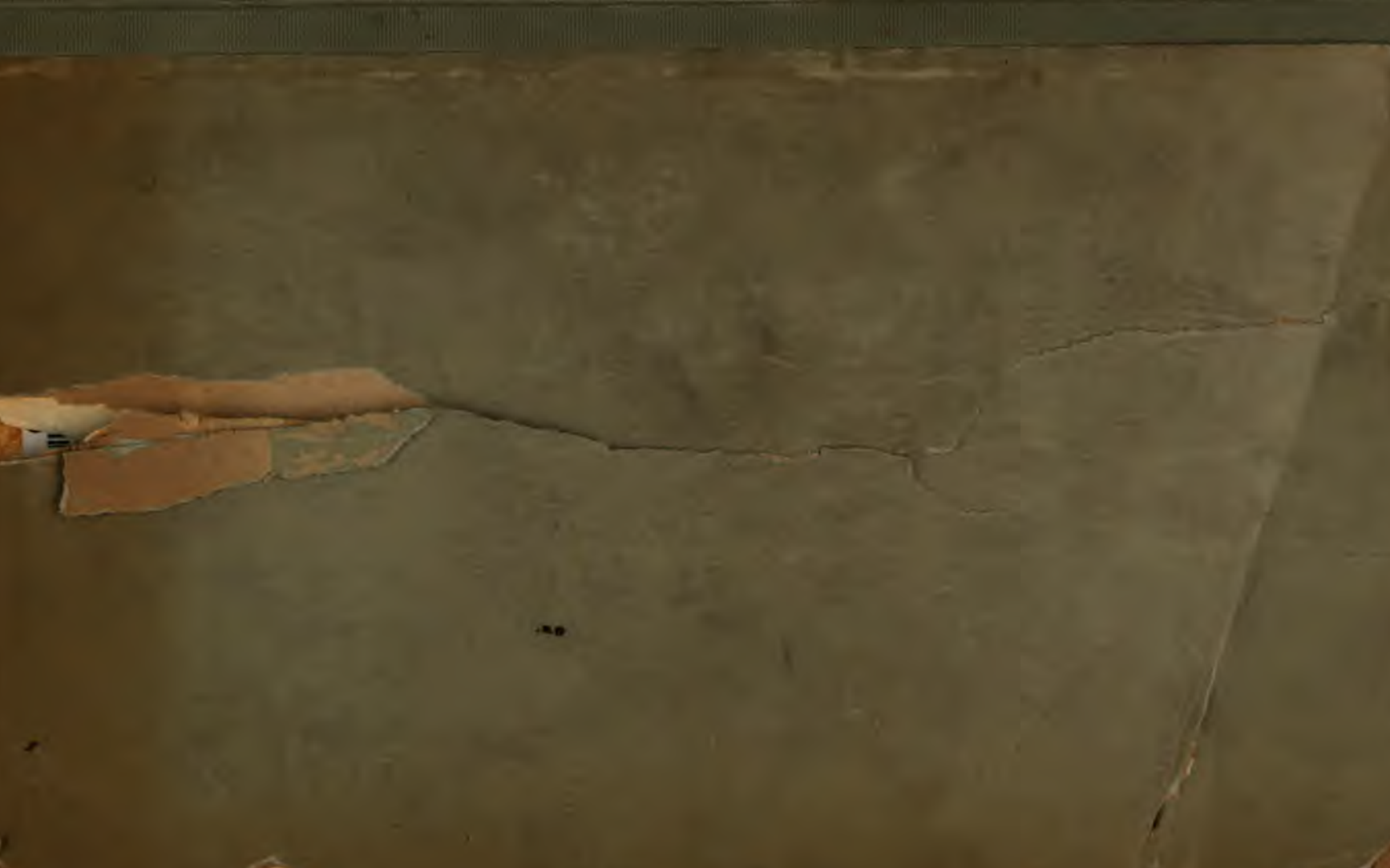
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